



Data Center Efficiency November 20, 2008 Austin Energy



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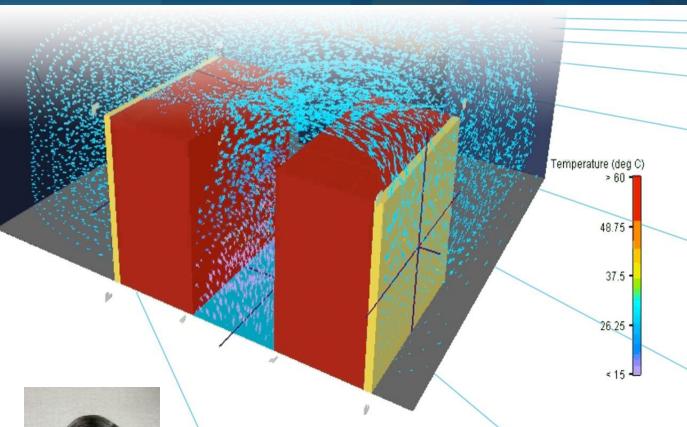
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Agenda

Introduction	Dale Sartor
Government programs	
Overview and Benchmarking	
IT issues	

BREAK

Environmental conditions	Bill Tschudi
HVAC systems	
Electrical systems	
Assessment tools	
Resources	



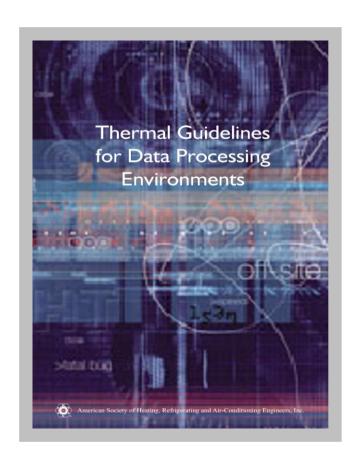
Environmental Conditions

Bill Tschudi, PE



Environmental conditions

- ASHRAE consensus between IT equipment manufacturers and HVAC professionals on appropriate temperature and humidity conditions
- Recommended and allowable ranges of temp and humidity
- Standard reporting of requirements



Design conditions - at inlet to IT equipment

		Table 2.1 Class 1, Class 2 and NEBS Design Conditions						
		Class 1 / Class 2	2	NEBS				
	Condition	Allowable Level	Recommended Level	Allowable Level	Recommended Level			
\Rightarrow	Temperature control range	59°F – 90°F ^{a,f} (Class 1) 50°F – 95°°F ^{a,f} (Class 2)	68°F – 77°F ^a	41°F – 104°F ^{c,f}	65°F – 80°F ^d			
	Maximum temperature rate of change	9°F. per hour ^a		2.9°F/min. ^d				
\Rightarrow	Relative humidity control range	20% - 80% 63°F. Max Dewpoint ^a (Class 1) 70°F. Max Dewpoint ^a (Class 2)	40% - 55%ª	5% to 85% 82°F Max Dewpoint°	Max 55% ^e			
	Filtration quality	65%, min. 30% ^b (MERV 11, min. MERV 8) ^b						

^aThese conditions are inlet conditions recommended in the ASHRAE Publication *Thermal Guidelines for Data Processing Environments* (ASHRAE, 2004).

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^bPercentage values per ASHRAE *Standard* 52.1 dust-spot efficiency test. MERV values per ASHRAE Standard 52.2. Refer to Table 8.4 of this publication for the correspondence between MERV, ASHRAE 52.1 & ASHRAE 52.2 Filtration Standards.
^oTelecordia 2002 GR-63-CORE

dTelecordia 2001 GR-3028-CORE

^eGenerally accepted telecom practice. Telecom central offices are not generally humidified, but grounding of personnel is common practice to reduce ESD.

fRefer to Figure 2.2 for temperature derating with altitude

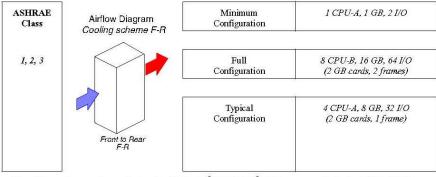
Design conditions at the inlet to IT equipment: recently revised by ASHRAE

	2004 Version	2008 Version
Low End Temperature	20 C (68 F)	18 C (64.4 F)
High End Temperature	25 C (77 F)	27 C (80.6 F)
Low End Moisture	40% Relative Humidity	5.5 C Dew Point (41.9 F)
High End Moisture	55% Relative Humidity	60% Relative Humidity & 15 C Dew Point (59 F Dew Point)

ASHRAE Thermal Report

XYZ Co. Model abc Server: Representative Configurations

	Condition								
;	Voltage 110 Volts								
	Typical Heat Kelease	Airflow ^a , Nominal		Airflow, Maximum at 35°C		Weight		Overall System Dimensions ^b (W × D × H)	
Description	watts	fim	(m ³ /h)	fm	(m ³ /h)	lbs	kg	in.	mm
Minimum Configuration	1765	200	680	600	1020	896	406	30 × 40 × 72	762 × 1016 × 1828
Full Configuration	10740	750	1275	1125	1913	1528	693	61 × 40 × 72	1549 × 1016 × 1828
Typical Configuration	5040	555	943	833	1415	1040	472	30 × 40 × 72	762 × 1016 × 1828

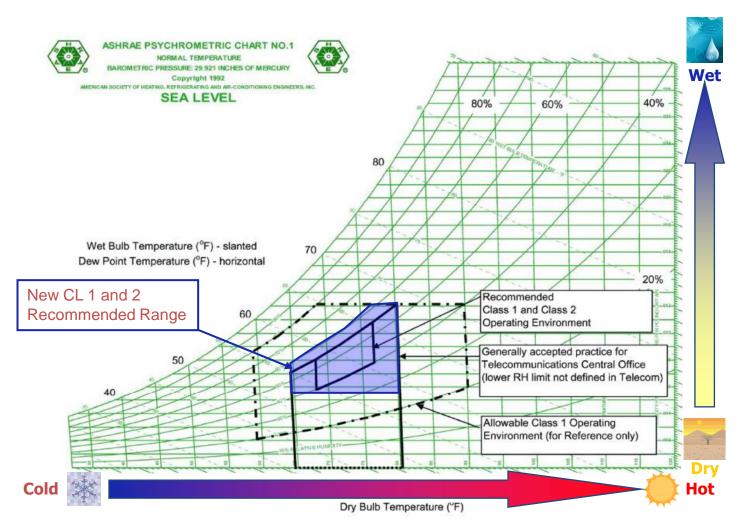


a. The airflow values are for an air density of 1.2 kg/m³ (0.075 lb/ft³). This corresponds to air at 20°C (68°F), 101.3 kPA (14.7 psia), and 50% relative humidity.

From ASHRAE's Thermal Guidelines for Data Processing Environments

b. Footprint does not include service clearance or cable management, which is zero on the sides, 46 in. (1168 mm) in the front, and 40 in. (1016 mm) in the rear.

Design conditions at the inlet to IT equipment



Humidity Ratio Pounds Moisture per Pound of Dry Air

Example server specification: (Dell PowerVault MD3000)

Environmental

Temperature:

- Operating: 10° to 35°C (50° to 95°F)
- Storage: -40° to 65°C (-40° to 149°F)

Relative humidity

- Operating: 20% to 80% (non-condensing)
- Storage: 5% to 95% (non-condensing)

Altitude

- Operating: -15 to 3048 m (-50 to 10,000 ft)
- Storage: -15 to 10,668 m (-50 to 35,000 ft)

Example server specification: Supermicro SYS-6015T

Operating Environment / Compliance

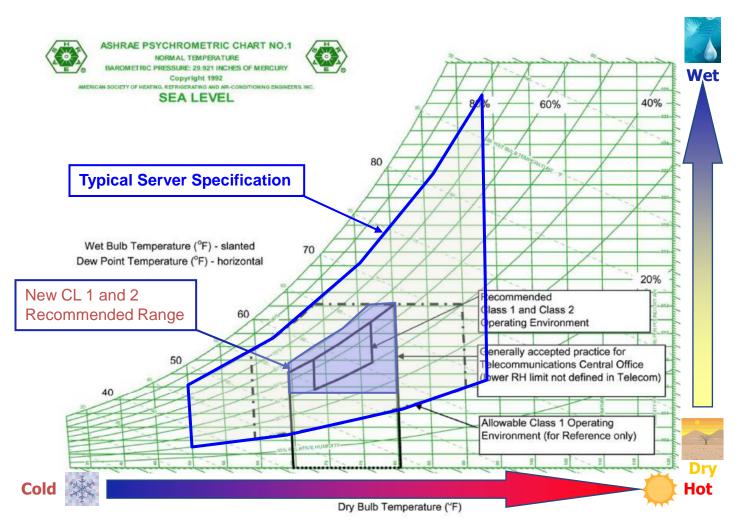
Environmental Specifications Operating Temperature: 10°C to 35°C (50°F to 95°F)

- Non-operating Temperature:
 - -40°C to 70°C (-40°F to 158°F)
- Operating Relative Humidity:

8% to 90% (non-condensing)

 Non-operating Relative Humidity: 5% to 95% (non-condensing)

Server specs exceed ASHRAE ranges



Humidity Ratio Pounds Moisture per Pound of Dry Air

Microsoft's data center in a tent



http://www.datacenterknowledge.com/archives/ 2008/09/22/new-from-microsoft-data-centers-intents/

"Inside the tent, we had five HP DL585s running Sandra from November 2007 to June 2008 and we had **ZERO failures** or 100% uptime. In the meantime, there have been a few anecdotal incidents:

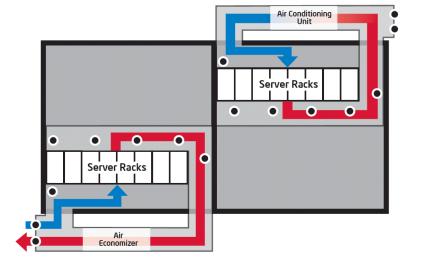
- Water dripped from the tent onto the rack. The server continued to run without incident.
- A windstorm blew a section of the fence onto the rack. Again, the servers continued to run.
- An itinerant leaf was sucked onto the server fascia. The server still ran without incident."

Slide 12

And from Intel a side-by-side comparison

Intel conducted a 10-month test to evaluate the impact of using only outside air to cool a high-density data center, even as temperatures ranged between 64 and 92 degrees and the servers were covered with dust.

 Intel's result: "We observed no consistent increase in server failure rates as a result of the greater variation in temperature and humidity, and the decrease in air quality. This suggests that existing assumptions about the need to closely regulate these factors bear further scrutiny."



See http://www.datacenterknowledge.com/archives/2008/09/18/intel-servers-do-fine-with-outside-air/

Lower humidity recommendation

Concern is electrostatic discharge (ESD)

- Recommended mitigation procedures
 - Personnel grounding
 - Cable grounding
- Recommended equipment
 - Grounding wrist straps on racks
 - Grounded plate for cables
 - Grounded flooring
 - Servers rated for ESD resistance
- Industry practices
 - Telecom industry has no lower limit
 - The Electrostatic Discharge Association has removed humidity control as a primary ESD control measure in their ESD/ANSI S20.20 standard

Lower humidity limit

- Tight humidity control is a legacy issue from days when paper products and tape were widely used
- Humidity controls are a point of failure and are hard to maintain
- Many data centers today operate without humidification or with malfunctioning humidity control
- Humidity control, if desired, should be provided through make-up air only
- More research is needed
- Humidity may be required for some physical media (tape storage, printing, etc.)
 - Old technology requiring humidification is not found in many data centers
 - It is best to segregate these items rather than humidify the entire data center

Many data centers have no humidification controls and operate successfully

Many different organizations including:

- Banks
- Medical service providers
- Server manufacturers
- Software firms
- Colocation facilities
- Major chip manufacturer
- Supercomputer facilities
- Animation studios

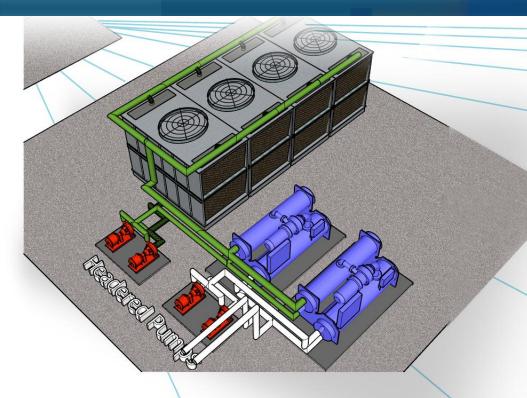
High humidity recommendation

Concern is over condensation and circuit bridging

- Some contaminants (hydroscopic salts) in high concentrations in combination with high humidity can deposit and bridge across circuits over time, causing current leakage or shorts.
- Unless you operate with very high humidity (≥80%) in a contaminated environment for long periods of time this phenomenon should not be a problem.
- Do you tightly control humidity for your home computer?
- More research is needed to determine if there is a basis for concern.

Environmental conditions take aways

- Use the entire ASHRAE recommended range in data center operation.
 - Provide the warmest supply temperatures that satisfy the equipment inlet conditions.
 - Control to the widest humidity range.
- Humidification does not protect against ESD, consider grounding and personnel practices in lieu of humidification.
- There is published scientific evidence that high humidity in combination with hydorscopic salts causes equipment problems
- Isolate equipment that needs tighter humidity or temperature control.

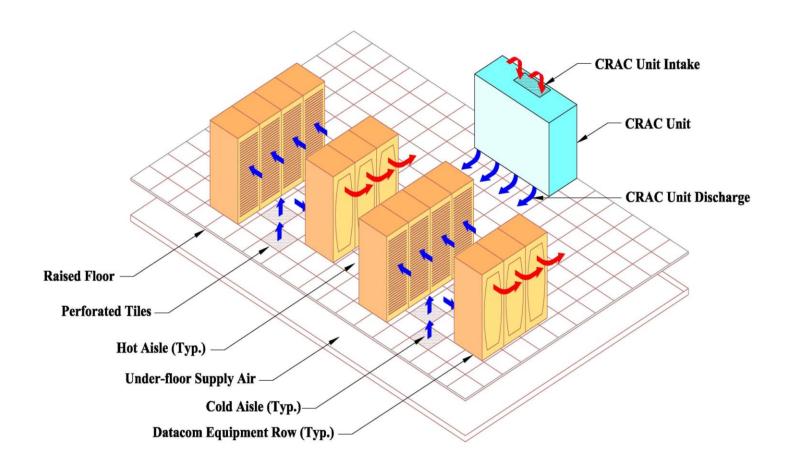




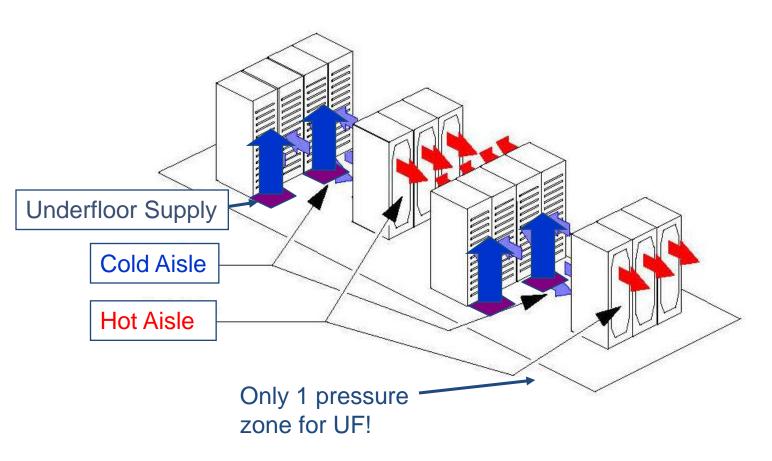
Air System Design

Air system design overview

- Data center layout
- Airflow configurations
 - Distribution: overhead or underfloor
 - Control: constant or variable volume
- Air management issues



Underfloor supply



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Vertical overhead (VOH) air distribution

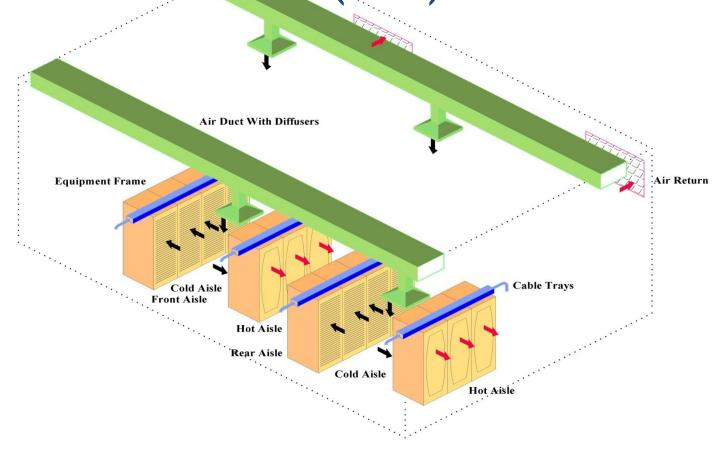
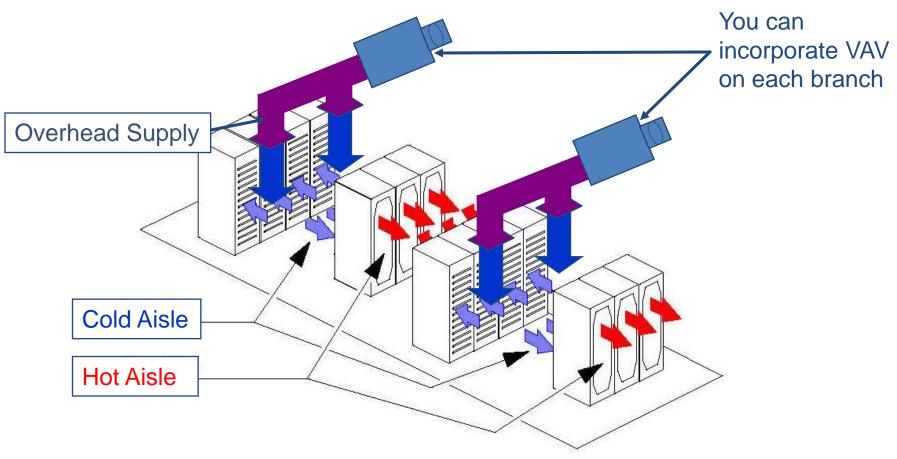


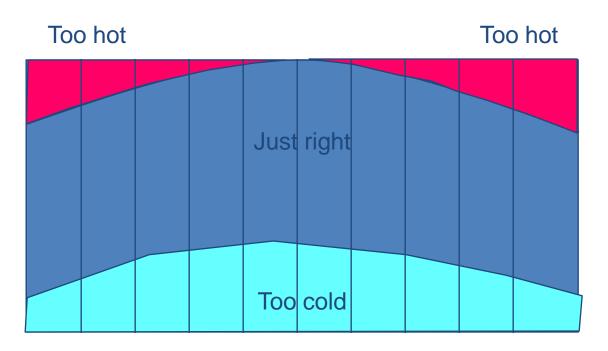
Figure 5.3 – Example Data Center with VOH Cooling Architecture

Overhead supply



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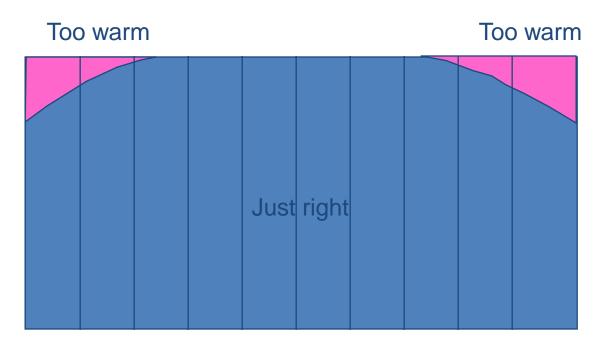
Typical temperature profile with under floor supply



Elevation at a cold aisle looking at racks

There are numerous references in ASHRAE. See for example V. Sorell et al; "Comparison of Overhead and Underfloor Air Delivery Systems in a Data Center Environment Using CFD Modeling"; ASHRAE Symposium Paper DE-05-11-5; 2005

Typical temperature profile with overhead supply



Elevation at a cold aisle looking at racks

Overhead vs. underfloor

	Issue	Overhead (OH) Supply	Underfloor (UF) Supply
>	Capacity	Limited by space and aisle velocity.	Limited by free area of floor tiles.
	Balancing	Continuous on both outlet and branch.	Usually limited to incremental changes by
			diffuser type. Some tiles have balancing
			dampers. Also underfloor velocities can
			starve floor grilles!
	Control	Up to one pressure zone by branch.	Only one pressure zone per floor, can
			provide multiple temperature zones.
	Temperature	Most uniform.	Commonly cold at bottom and hot at top.
	Control		
>	First Cost	Best (if you eliminate the floor).	Generally worse.
	Energy Cost	Best.	Worst.
	Flexibility	Harder to reconfigure	Easiest
	Aisle Capping	Hot or cold aisle possible.	Hot or cold aisle possible.
/			

Airflow design disjoint

 IT departments select servers and racks having airflow and cooling requirements

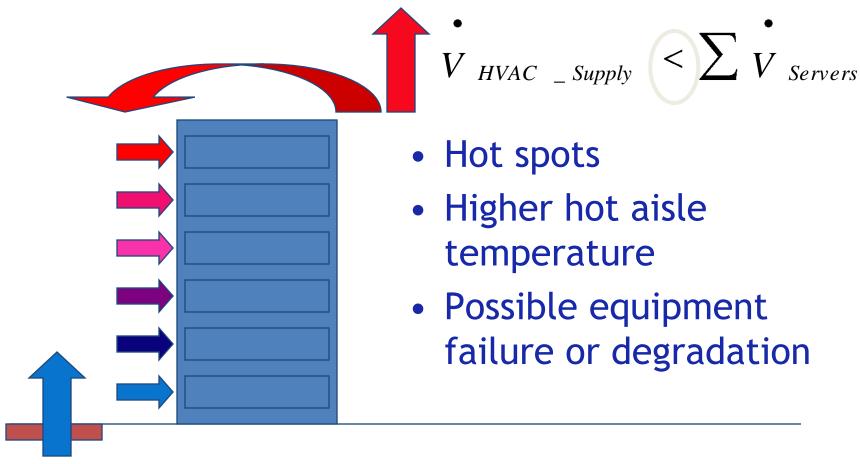
Engineers size the facility fans and cooling

capacity

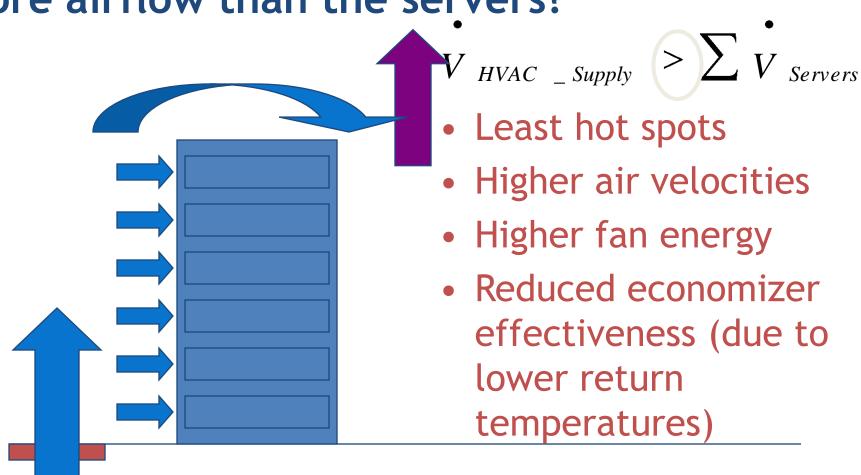
What's missing in this picture?



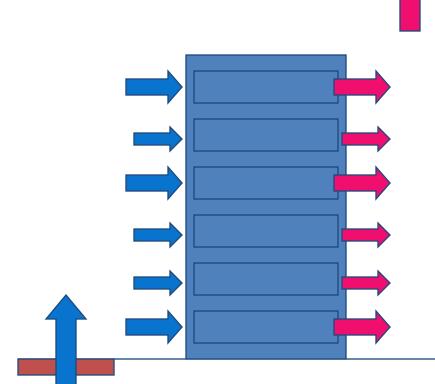
What happens when the HVAC systems have less airflow than the servers?



What happens when the HVAC systems have more airflow than the servers?



In a perfect world, variable supply and server fans...

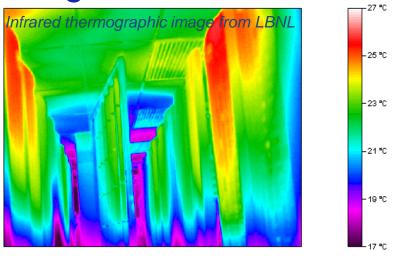


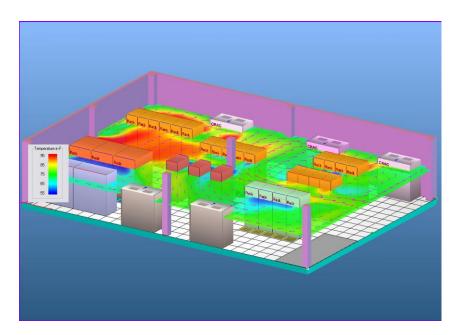
- $\stackrel{\bullet}{V}_{HVAC}$ _Supply $\approx \sum \stackrel{\bullet}{V}_{Servers}$
 - Partial flow condition
 - Best energy performance but tricky to control
 - Works best with aisle containment

How do you balance airflow?

- Spreadsheet
- CFD
- Monitoring, infrared thermography or other site measurements

Using aisle containment





CFD image from TileFlow http://www.inres.com/Products/TileFlow/tileflow.html, Used with permission from Innovative Research, Inc.

Wireless Sensor Network

- Wireless sensor network
- "Self-organizing" nodes
- 802.15.4 (not 802.11)
- Multi-hop routing
- Non-invasive installation
- 2 internal & 6 external sensors per node
- Can measure temp., humidity, pressure, current, liquid flow, liquid presence & particle count.
- Low cost(10%-20% of standard DDC costs)

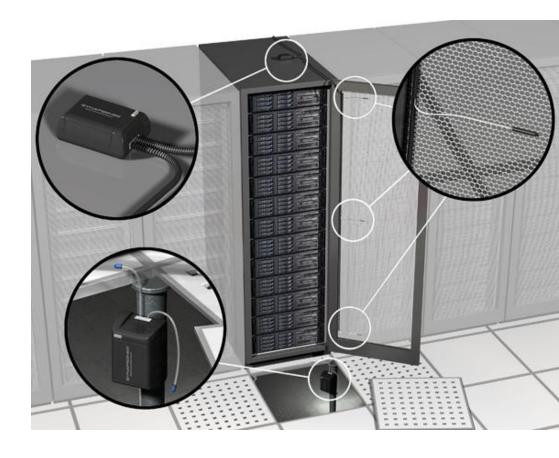
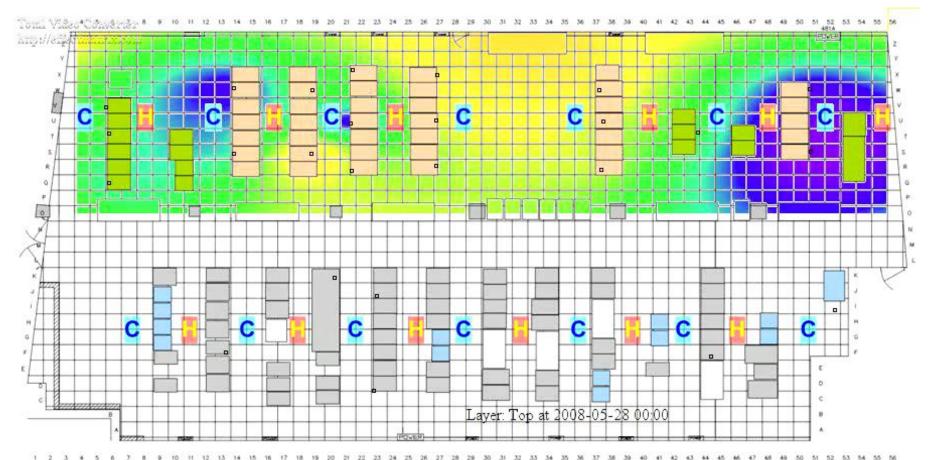


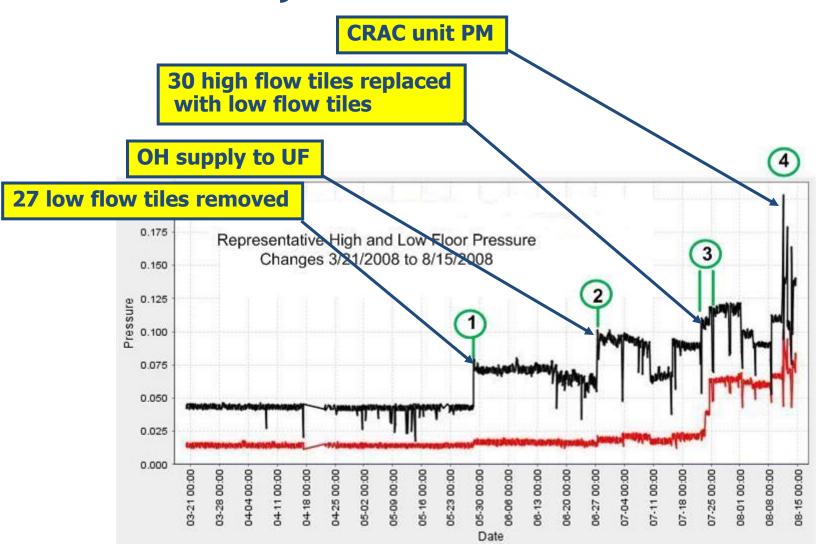
Image: SynapSense

real time visualization



This is a dynamic picture and tracks progress when making retrofits

Case study



Case study results (so far)

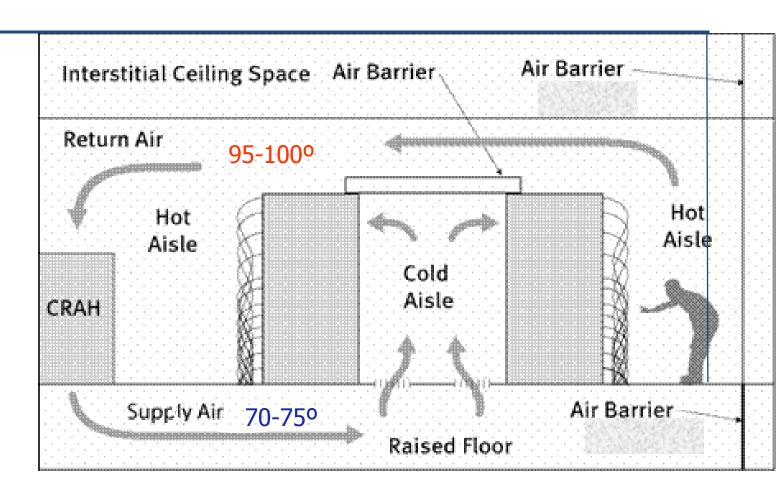
- 7% increase (~30kW) in IT load with 8% less fan energy
- CRAC unit setpoints 3°F warmer
- Fewer hot spots
- (1) 15 ton unit turned off
- (1) extra 15 ton unit on-line but redundant
- The wireless sensor network enabled facilities to visualize, track and fine tune many changes in the data center including tuning of the floor tiles

Isolating hot or cold aisles

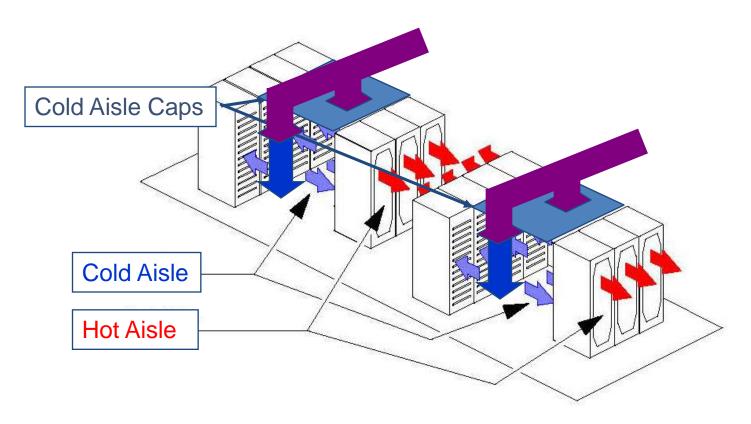
- Energy intensive IT equipment needs good isolation of "cold" inlet and "hot" discharge.
- Supply airflow can be reduced if no mixing occurs.
- Overall temperature can be raised in the data center if air is delivered to equipment without mixing.
- Cooling systems and economizers use less energy with warmer return air temperatures.
- Cooling coil capacity increases with warmer air temperatures.

Cold aisle containment, underfloor supply

With cold aisle containment, the general data center is hot 95-100F



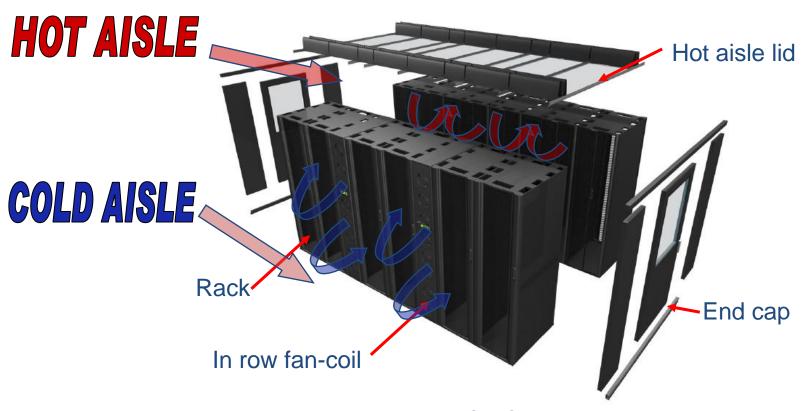
Cold aisle containment, overhead supply



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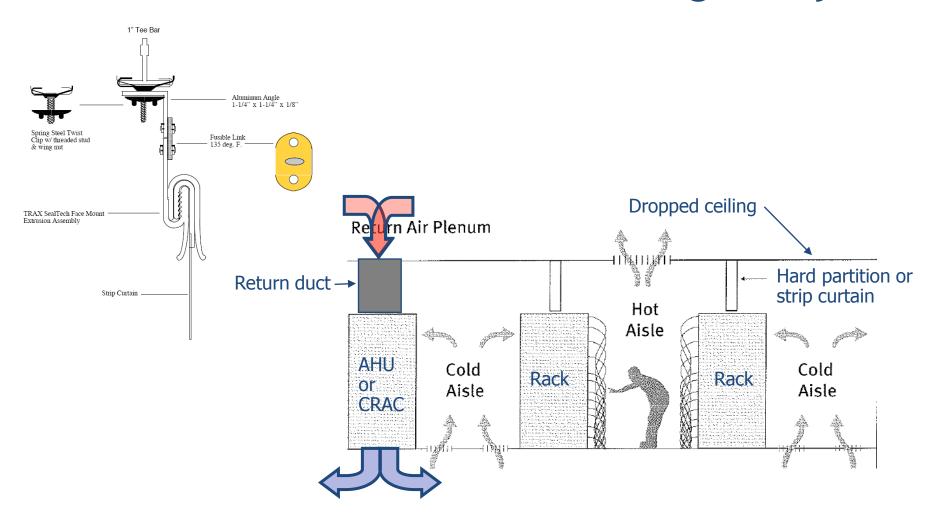
Hot aisle containment with in row cooling

With hot aisle containment, the general data center is neutral (70-75F)

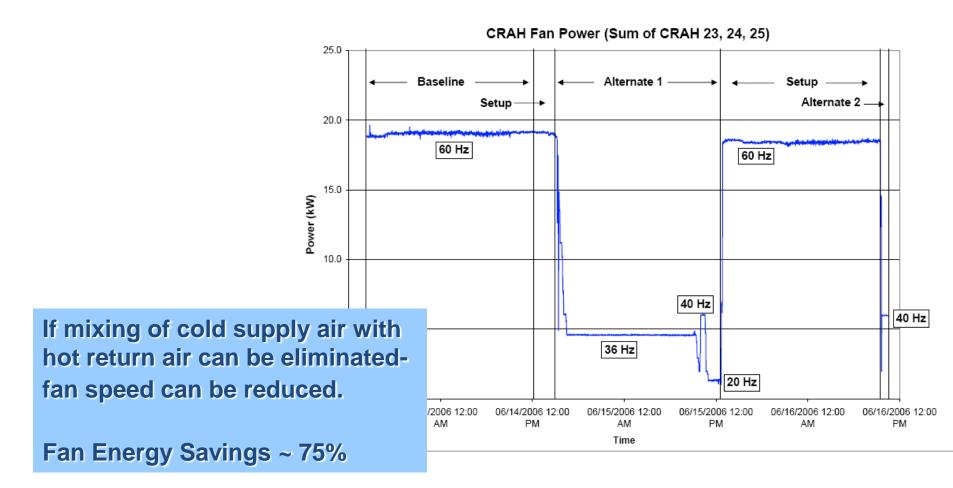


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Hot and cold isolation the frugal way

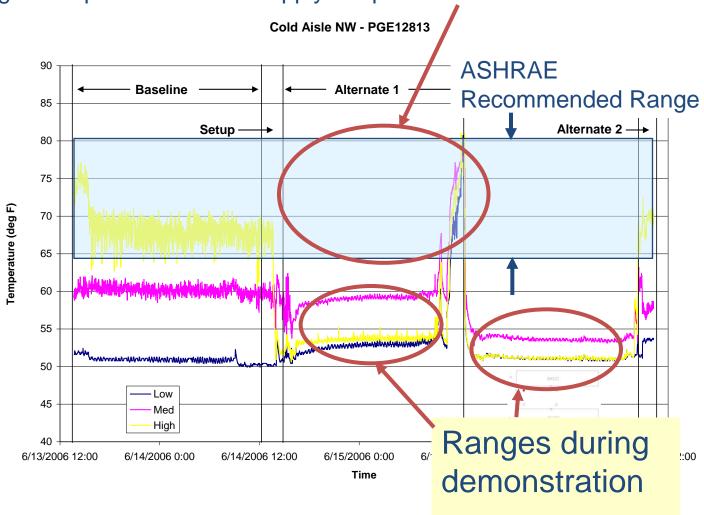


LBNL air management demonstration



LBNL air management demonstration

Better airflow management permits warmer supply temperatures!

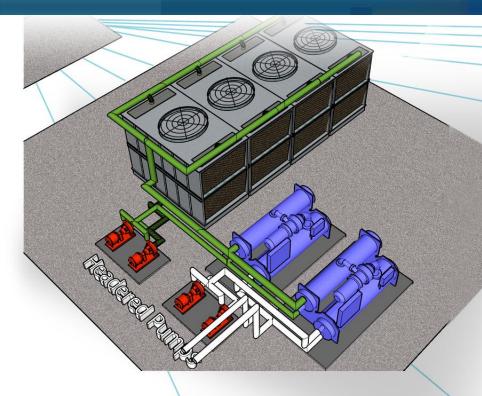


Cold and hot isolation review

- Can be retrofit.
- Either hot or cold aisle containments work.
- Hot aisle (or in-rack containment) will make the general data center more comfortable.
- You have to think about fire protection with containment (sprinkler and FM200).
- Isolation of hot and cold is more important than the type of supply (overhead or underfloor).

Best practices for air delivery

- Arrange racks in hot aisle/cold aisle configuration.
- Plug leaks in floor and racks
- Try to match or exceed server airflow by aisle.
 - Get thermal report data from IT if possible.
 - Plan for worst case.
- Get variable speed or two speed fans on servers if possible.
- Provide variable airflow fans for CRAC/H or AHU supply.
- Consider using air handlers rather than CRAHs for improved performance (and ability to use outside air).
- Provide hot and cold isolation.
- Draw hot air return from as high as possible.
- Consider CFD or other visualization techniques to inform the design.





Free Cooling

Free cooling overview

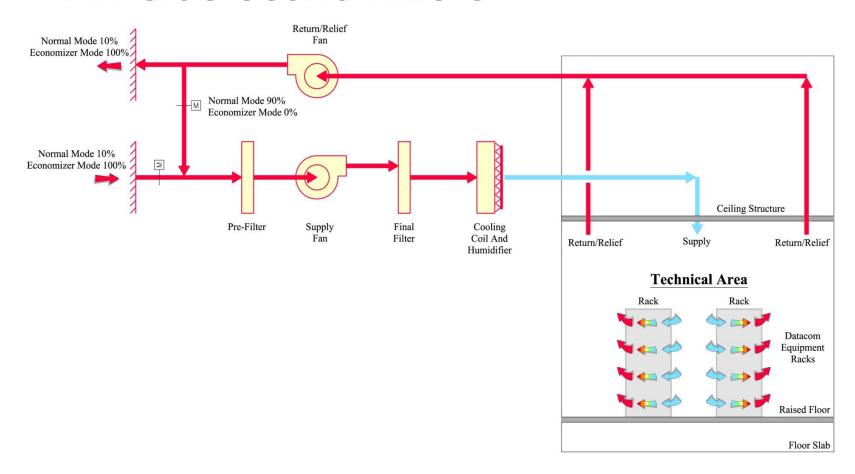
Air side economizers

- The potential energy savings of air-side economizers in the 16 ASHRAE climates
- The relationship of humidification and air-side economizers
- Challenges to implementing airside economizers
- A combined air-side economizer with direct evaporative cooling (an emerging technology)
- Non-energy benefits of air-side economizers

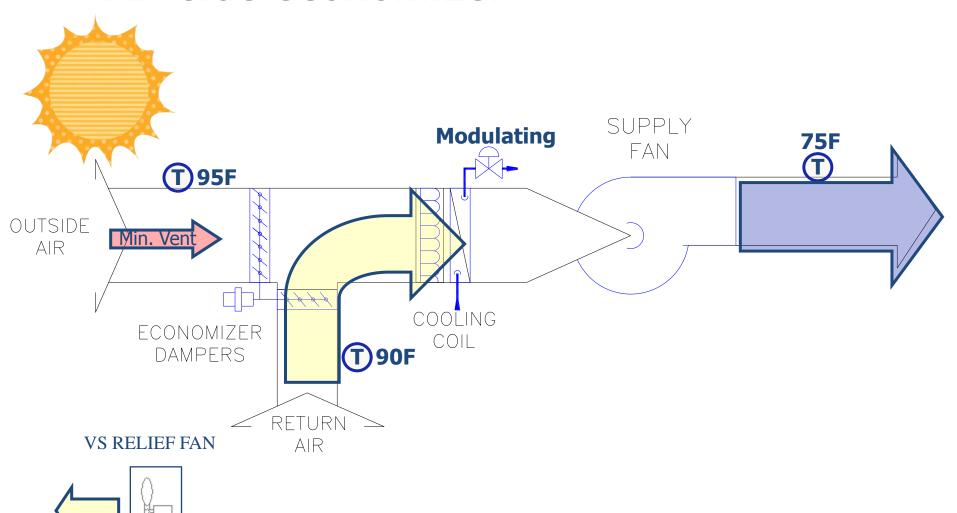
Water side economizers

- The potential energy savings of water-side economizers
- Challenges to implementing water-side economizers
- Non-energy benefits of water-side economizers

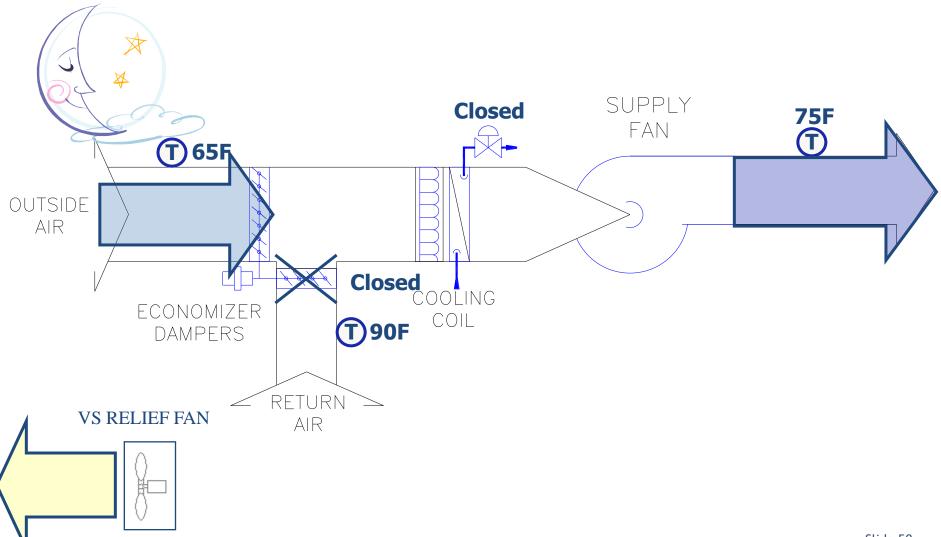
Air-side economizers



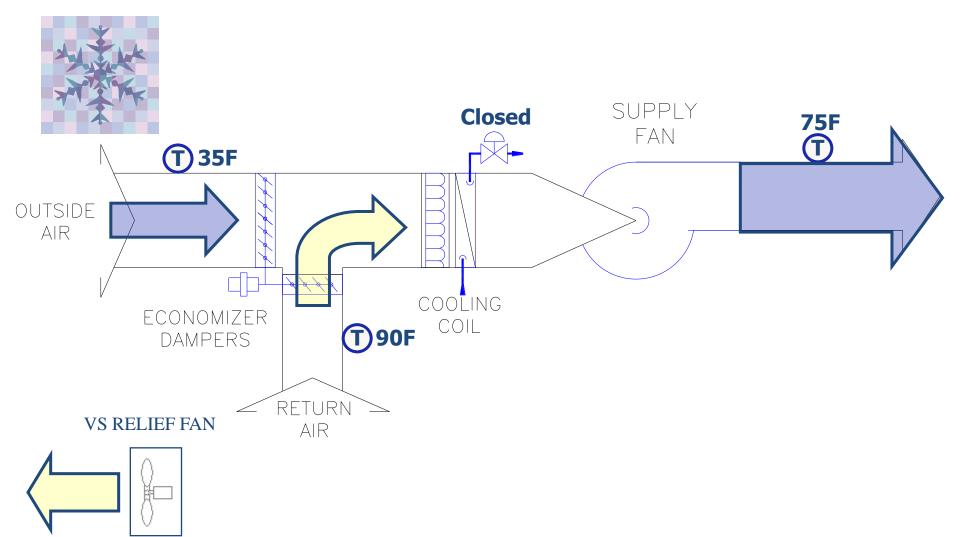
Air-side economizer



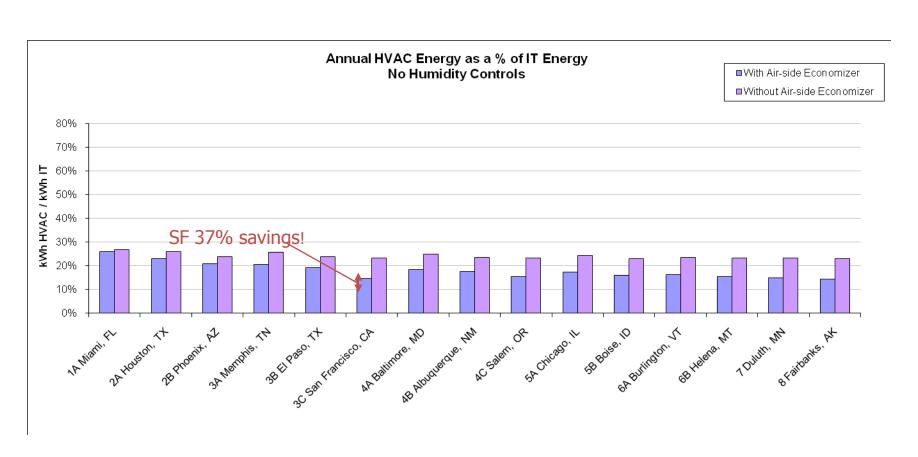
Air-side economizer



Air-side economizer



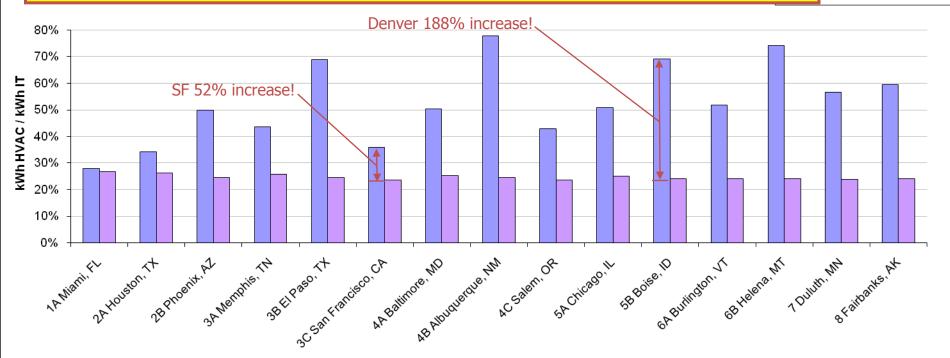
Air-side economizer savings: no humidification and code minimum water-cooled chilled water plant



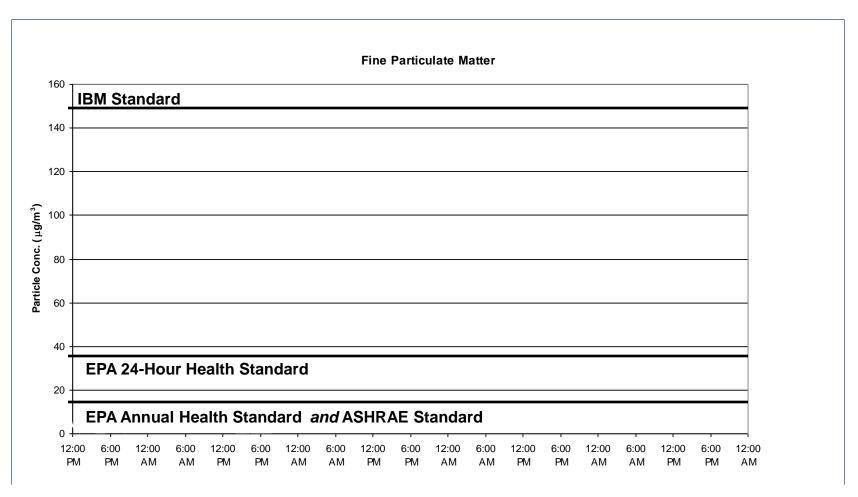
Air-side economizer savings: with humidification and code minimum water-cooled chilled water plant

These results are based on humidifying to the middle of the old ASHRAE "recommended" envelope ~51F tdp The new "recommended" lower limit is 41.9°F tdp The excess energy shown here is the result of using a standard economizer high-limit switch. Adding a minimum OSA dew-point switch would fix the problem.

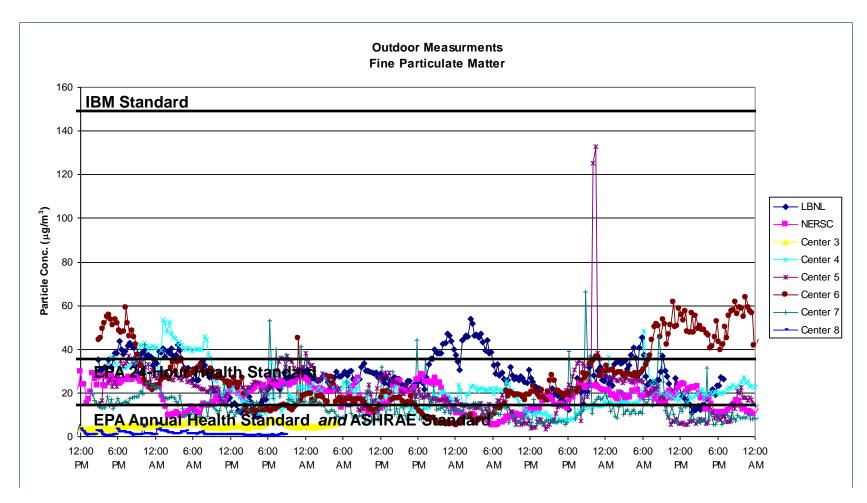
Air-side Economizer out Air-side Economizer



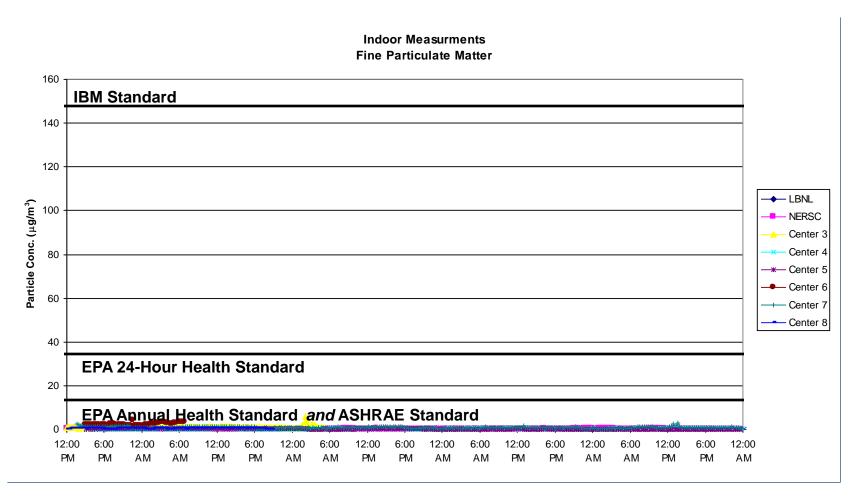
What about contamination? "My center must be closed."



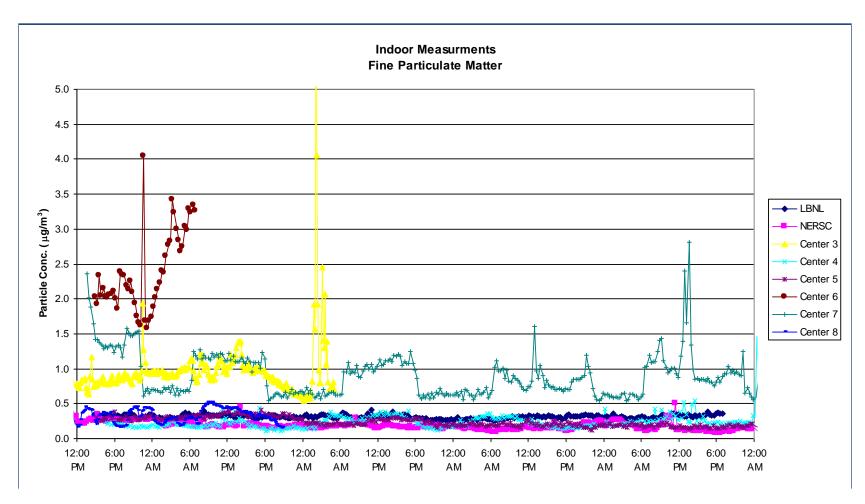
Outdoor measurements



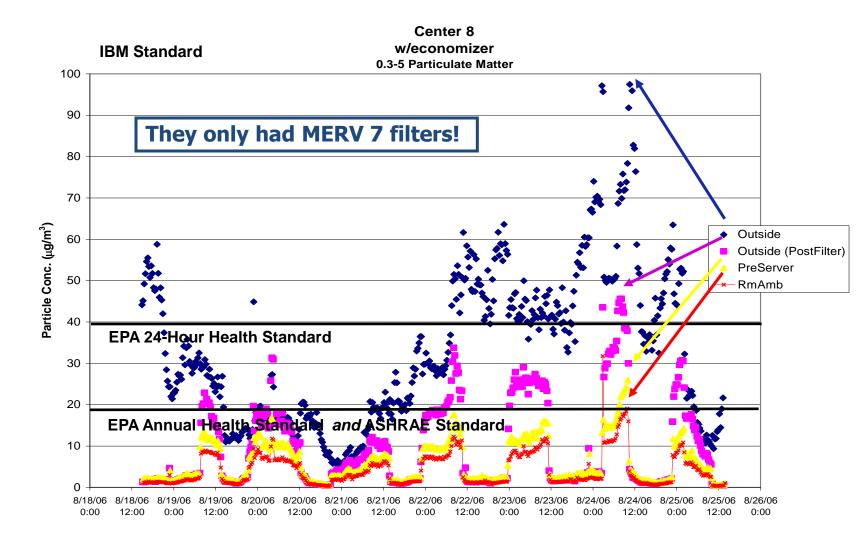
Indoor measurements



Indoor measurements



LBNL particulate study - data center w/economizer



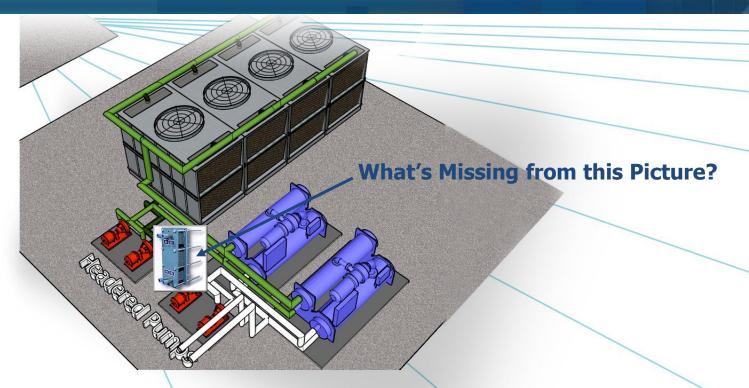
Wet-bulb air economizer review

- Advantages
 - Extends hours of free cooling
 - Provides non-compressor cooling
 - Provides minimum humidification (if you care)
 - No outside air introduced (if you worry about that)
 - Increases reliability by providing a redundant noncompressor

- Disadvantages
 - Capital cost
 - Increased fan energy
 - Spatial requirements

Air-side economizer summary

- Can improve the reliability of the plant
- Generally improves indoor air quality
- Humidity control can negate savings
 - If used, lock out the economizers when the OSA is below the humidity control dewpoint temperature setpoint
- Particulates shouldn't be an issue better filtration could be provided for added assurance (MERV 13 or higher)
- Work best with high return temperatures (aisle containment)
- Consider a direct evaporative stage to increase the hours of free cooling
- Consider controls to prevent smoke from outside being pulled into the data center (e.g. grass fire)





Water Side Economizers

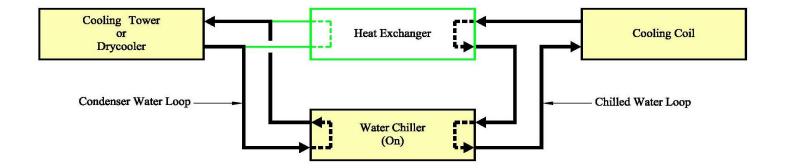
Free cooling

 Use cooling towers and heat exchanger to produce chilled water

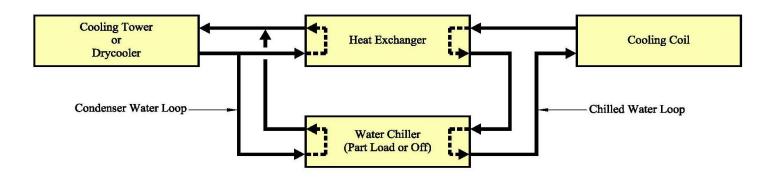
• Turn off chiller







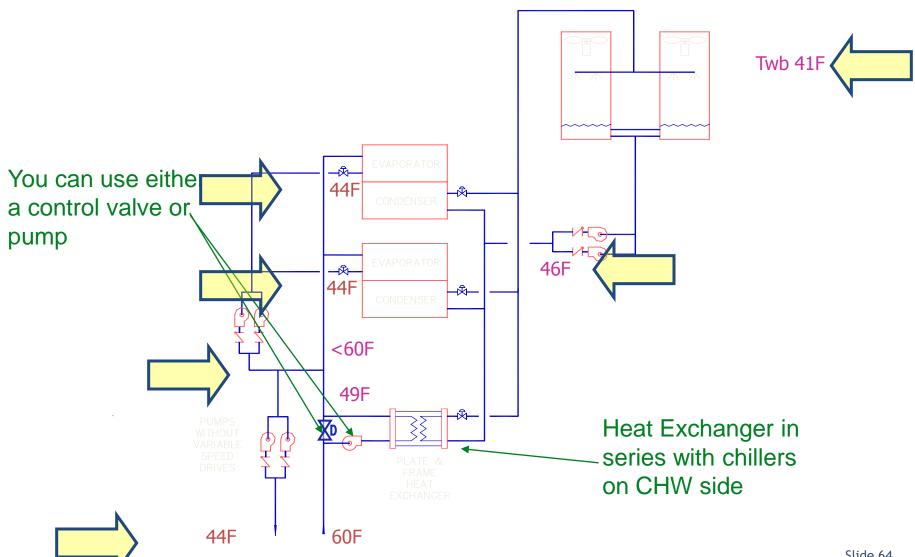
NORMAL CHILLER PLANT OPERATION (CONDENSER WATER TEMPERATURE ABOVE COIL DESIGN TEMPERATURE)



INDIRECT WATER-SIDE ECONOMIZER OPERATION (CONDENSER WATER TEMPERATURE BELOW COIL DESIGN TEMPERATURE) (INTERGRATED ARRANGEMENT SHOWN IN THIS DIAGRAM, ALLOWING FOR PARTIAL ECONOMIZER OPERATION AS A PRE-COOLER)

indirect water-side economizer

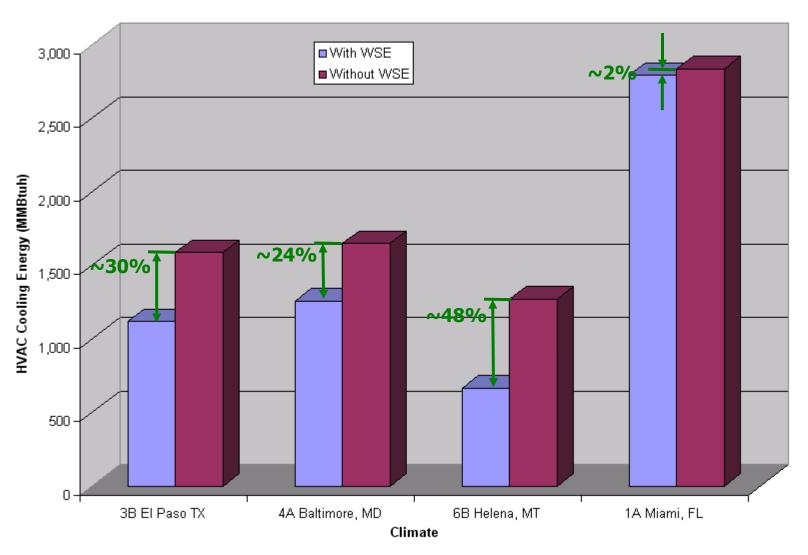
Integrated water-side economizer



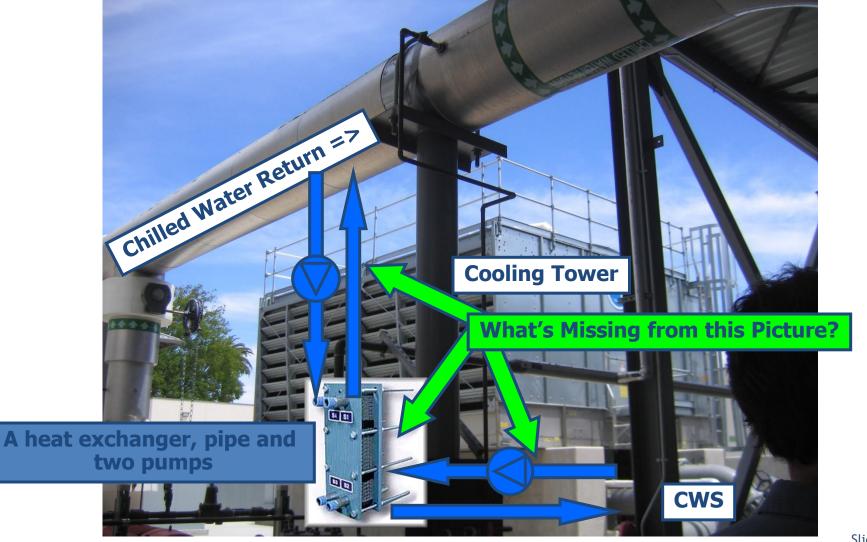
Example water side economizer savings

- Example based on 200,000 sf office building with ~ 110 tons of data center load.
- Location Pleasanton CA (ASHRAE Climate 3B)
- (2) 315 ton chillers (630 tons total).
- Building has air-side economizer.
- Data center has CRAH units.
- Water-side economizer on central plant with HX (integrated, see previous slide)

Example water side economizer savings



Chilled water plant in Santa Clara, CA



Implementing water economizers

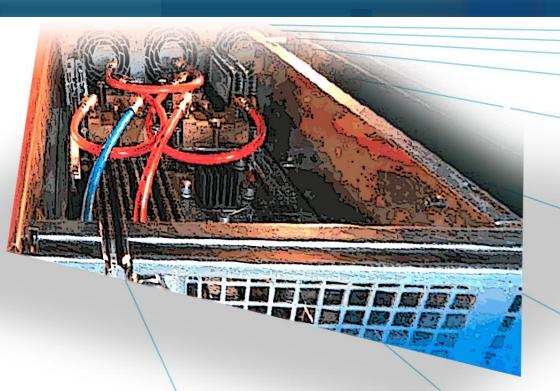
- Put the HX on the plant CHW return line in series <u>NOT</u> in parallel with the chillers
- You need head pressure controls for chillers and other water-cooled equipment
- Works best with CHW reset (the warmer the better)
- Works best if you design coils for high Delta-T
- Consider oversizing towers
- Design towers for low flow

Non-energy advantages of water side economizers

- Redundancy
- Limited ride-through if chillers trip
- Utilizes redundant towers

Free cooling take aways

- Air- and water economizers can save significant energy if properly designed and controlled.
- Air- economizers can increase energy usage if you have humidity controls.
- Air-economizers do increase particulates but these can be addressed with standard filtration.
- Water economizers should be integrated by installing free cooling heat exchanger in series with the chillers.
- Many utilities offer rebates for economizer systems.





Liquid Cooling Systems

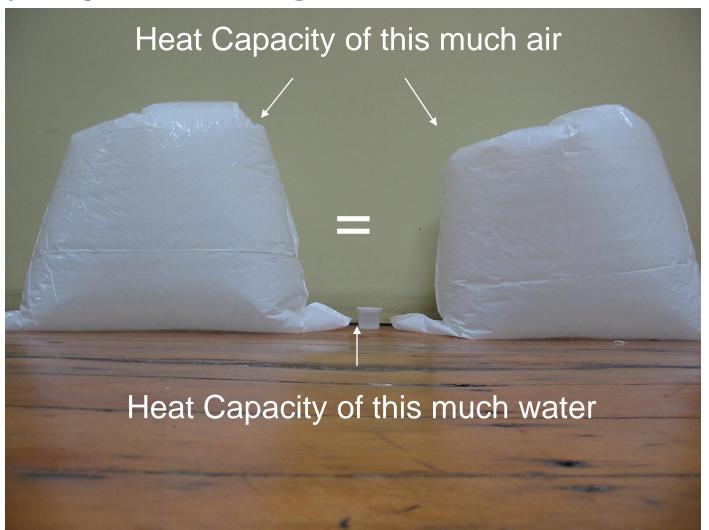
Outline

- Why liquid cool
- Liquid cooling options
 - Rack and row cooling
 - On board cooling
- Energy Benefits
- Interface with free cooling

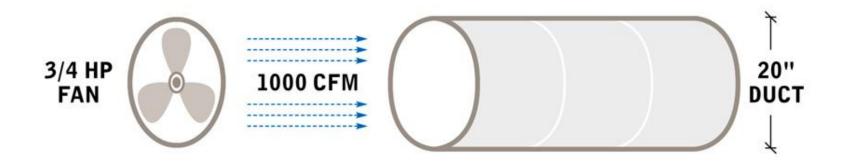
Air cooling issues

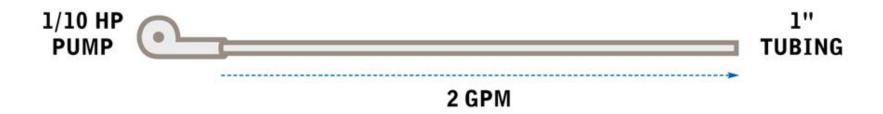
- Limitations on the data densities served
- Air delivery limitations
- Real estate
- Working conditions
 - Hot aisles are (should be) uncomfortably hot
- Costly infrastructure
- High energy costs
- Management over time
- Reliability

Why liquid cooling?

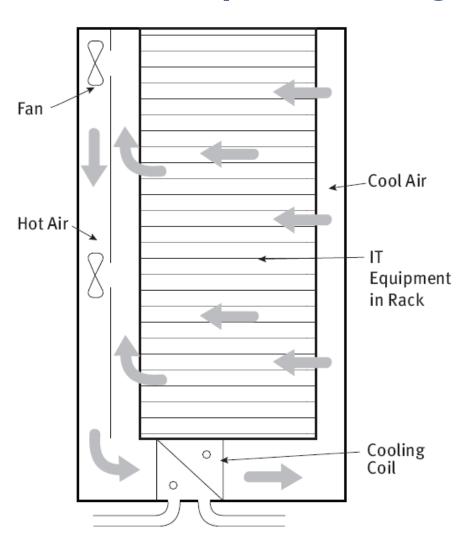


Fans move energy less efficiently





In rack liquid cooling



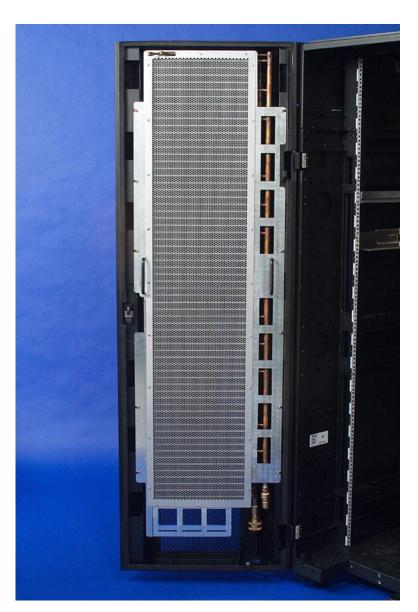
Close coupling between cooling source and server

However, some of these solutions might present challenges to redundancy and increase maintenance In rack liquid cooling -

Racks with integral coils



Rear door cooling



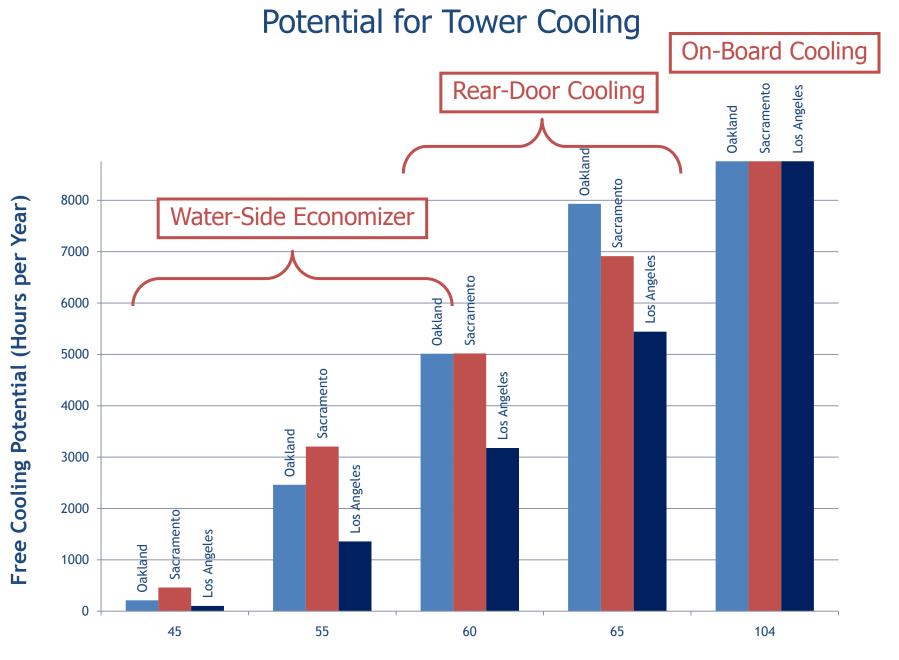
On board cooling





Comparison of conventional cooling to liquid cooling - 1,000 kW data center load

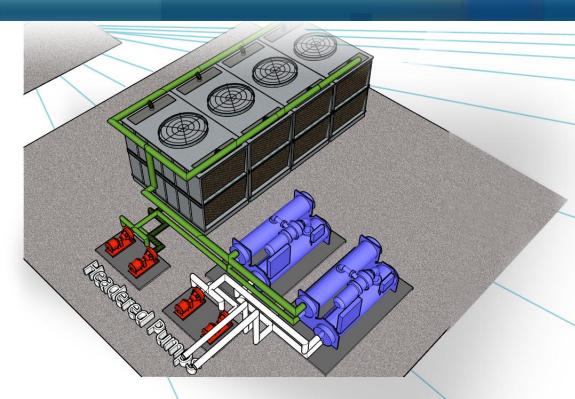
	Cooling Towers and Pumps	Chiller	Chilled Water Pumps	Fans	Other	Total Power (kW)	% SAVINGS
Traditional System - 45 Deg F Chilled Water	70	500	50	150	n/a	770	N/A
Liquid Cooled with Fans in the Rack - 55 Deg F Chilled Water	70	425	50	100	n/a	645	16%
Liquid Cooled without fans in the rack - 55 Deg F Chilled Water	70	425	50	0	n/a	545	29%
Liquid Cooled directly couple with CPU - 70 to 80 deg F Chilled Water	70	0	50	0	Room A/C - 245	365	53%



Chilled Water Design Temperature (Degrees F)

Liquid cooling take aways

- Liquid has greater heat removal capacity
- Pumps use less energy than fans to remove the same amount of heat
- Coupling heat removal to the source eliminates mixing
- A wide variety of commercially available liquid solutions are available
- The potential for energy savings is large
- Redundancy is a challenge for some liquid cooling technologies
- Water side free cooling can provide cooling with reduced chiller operation for much of the year





Central Chilled Water Plants

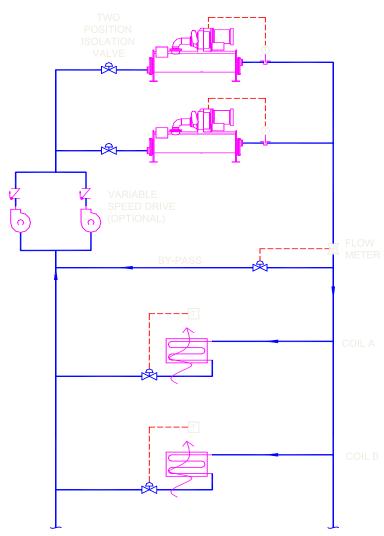
Central plant overview

- Most chilled water plants are sub-optimal yet run 24x7
- Efficiency issues are well understood
- Resources are available (e.g. ASHRAE)
- Air- VS Water-Cooled Chillers
- Best Practices

Variable flow

Primary-only, Multiple Chillers

- Advantages
 - Low installed cost.
 - Low energy cost.
- Disadvantages
 - More complex controls.
 - Can lose chillers if you don't stage them correctly.



Variable flow

Primary/Secondary, Multiple Chillers and Coils

Advantages

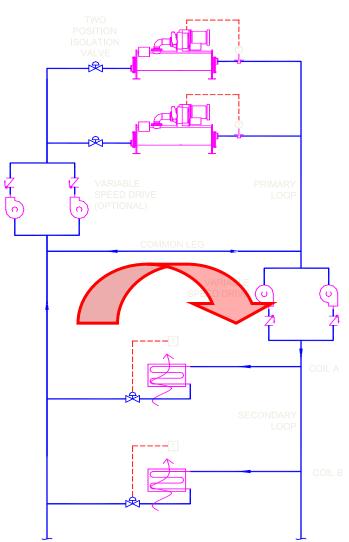
- Simpler controls.
- Easier to keep chillers online.

Disadvantages

- Higher installed cost.
- Higher pumping energy.
- Higher chiller energy as you have to stage the chillers on flow not load.

Mitigation

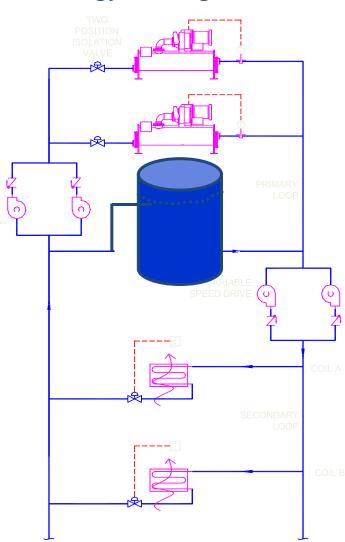
- Stage chillers by flow.
- Put check valve in common leg.



Variable flow

Primary/Secondary with thermal energy storage

- Advantages
 - No chiller staging problems
 - Peak shaving
 - Back up data center & chillers
 - Fire protection water source
 - Secondary source for cooling towers
- Disadvantages
 - Installed cost
 - Space

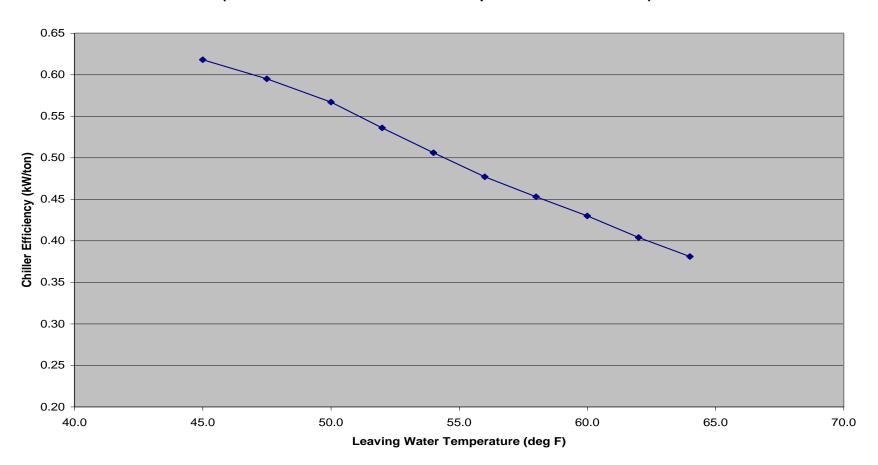


Primary-only vs. Primary/Secondary

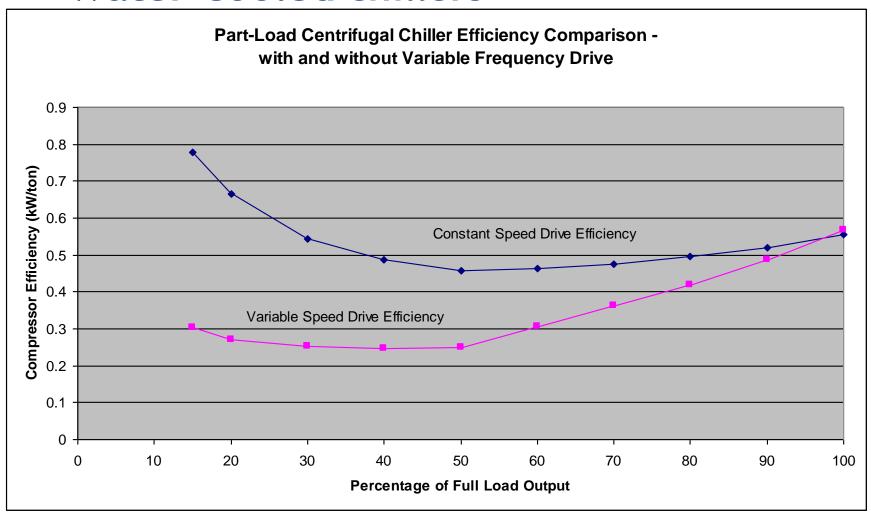
- Use primary-only systems for:
 - Plants with many chillers (more than three) and with fairly high base loads where the need for bypass is minimal or nil and flow fluctuations during staging are small due to the large number of chillers; and
 - Plants where design engineers and future on-site operators understand the complexity of the controls and the need to maintain them.
- Otherwise use primary-secondary
- Consider Primary-secondary with thermal energy storage

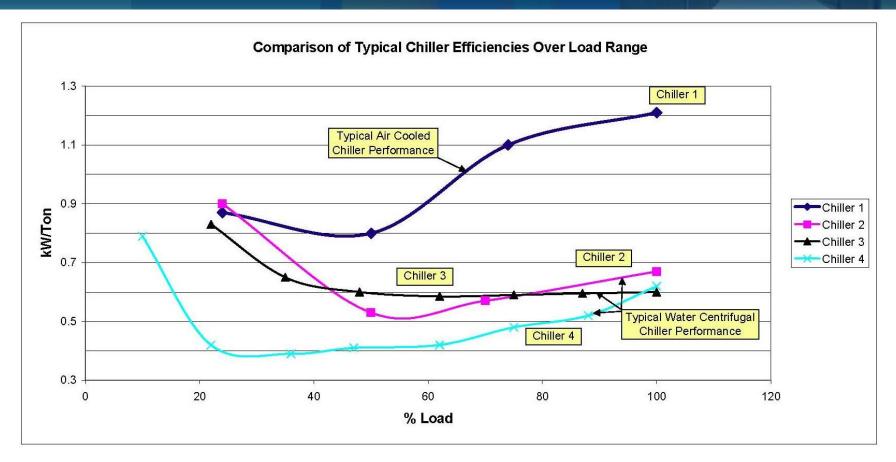
Water-cooled chillers

Sample Chiller Efficiency as a Function of Leaving Chilled Water Temperature (with Chilled Water Differential Temperature held Constant)



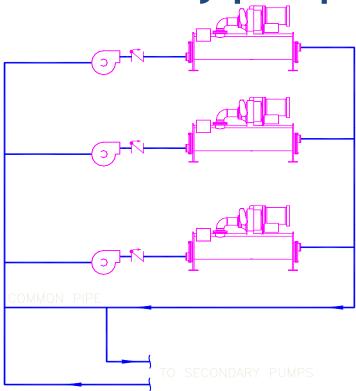
Water-cooled chillers





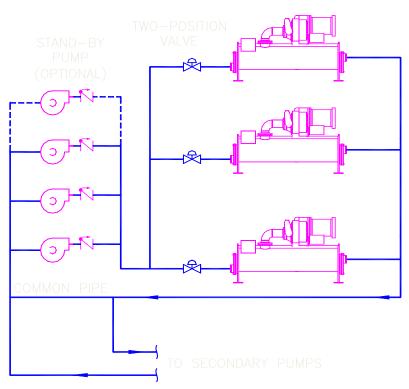
- Water cooled chillers are significantly more efficient than air cooled, especially centrifugal variable speed chillers at low loads (Chiller 4).
- Variable or primary-secondary controls are recommended.
 Prepared by DLB
 Associates

Primary pump options



Dedicated Pumping Advantages:

- Less control complexity
- Custom pump heads w/ unmatched chillers
- Usually less expensive



Headered Pumping Advantages:

- Better redundancy
- Valves can "soft load" chillers with primary-only systems
- Easier to incorporate stand-by pump

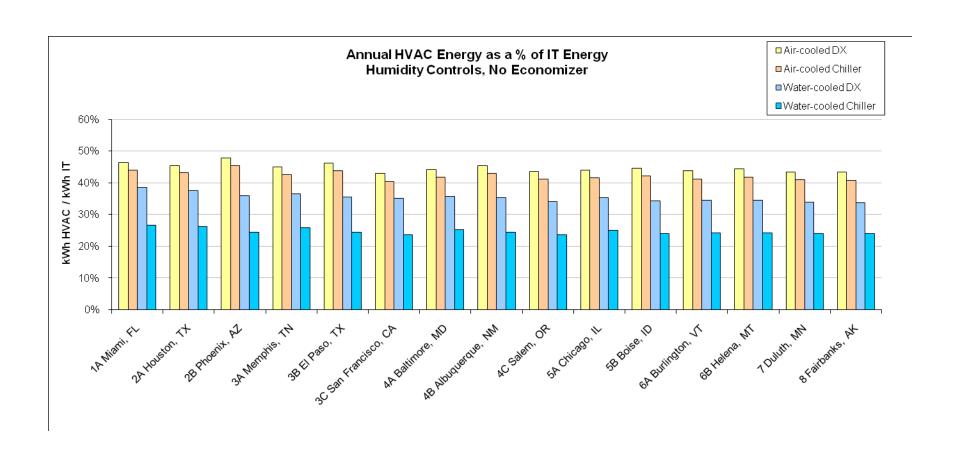
Tower fan control

- One-speed control is almost *never* the optimum strategy regardless of size, weather, or application
- Two-speed 1800/900 rpm motors typically best life cycle costs at mid-1990 VSD costs, but...
- VSDs may be best choice anyway
 - Costs continue to fall
 - Soft start reduces belt wear
 - Lower noise
 - Control savings for DDC systems (network card options)
 - More precise control
- Pony motors are more expensive than two-speed but offer redundancy
- Multiple cell towers should have speed modulation on at least 2/3 of cells (required by ASHRAE 90.1)

Tower efficiency guidelines

- Use Propeller Fans
 - Avoid centrifugal except where high static needed or where low-profile is needed and no prop-fan options available.
 - Consider low-noise propeller blade option and high efficiency tower where low sound power is required.
- For data centers and other 24/7 facilities, evaluate oversizing to 80 gpm/hp at 95 F to 85 F @ 75 F WB

Type of HVAC system, all climates

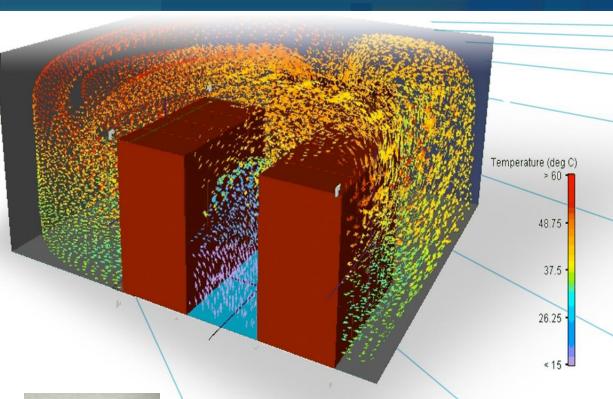


Where to learn more

- CoolTools Design Guide
 - http://taylorengineering.com/publications/design_guides.shtml

Chilled water plant best practices

- Use 2-way valves on all loads.
- Use oversized headers to balance loads and consider a loop type distribution system.
- Consider primary-only unless you have a chilled water storage tank (which is piped in the common leg).
- Use water-cooled chillers where possible.
- Consider chilled water storage for make-up water, peak shavings and ride-through in chiller staging.
- Put VSDs on everything (pumps, fans and chillers).





Data Center Controls

Control issues

- Temperature Control
- Humidity Control
- Airflow Control
- Feedback and Diagnostics
- IT Integration
- Others

Temperature control

Design Conditions

- Maintain inlet conditions at servers between 64°F and 80°F.
 - 59°F to 90°F allowable.
 - At ~77°F two speed and variable speed server fans speed up (using more IT fan energy).

Best practice

- Provide feedback from racks.
 - Hardwired or wireless EMCS sensors.
 - Network data exchange with server on-board sensors.
- Reset supply temperatures upward to keep most demanding rack satisfied (but below 77F).
- Can have local temperature zones with distributed CRAC/CRAH/AH units.

Novel control strategies

 Control of computer room air handlers using wireless temperature sensors

 Control of computer room air handlers using temperature sensors inside the IT equipment

Humidity control

- Avoid if at all possible
 - High humidity is usually limited by cooling coil dew-point temperature.
 - Low humidity limit is not well supported (see previous slides).
- If you decide to humidify, do all of the following:
 - Use high quality dew-point sensors located in the data center floor (Vaisala see NBCIP report: http://www.buildingcontrols.org/publications.html).
 - Use adiabatic (not steam or infrared) humidifiers.
 - Direct Evaporative Media.
 - Ultrasonic (but note that DI or RO water is required)
 - Best to provide on MUA unit.
 - Control all humidifiers together if distributed.

Example survey of CRACs

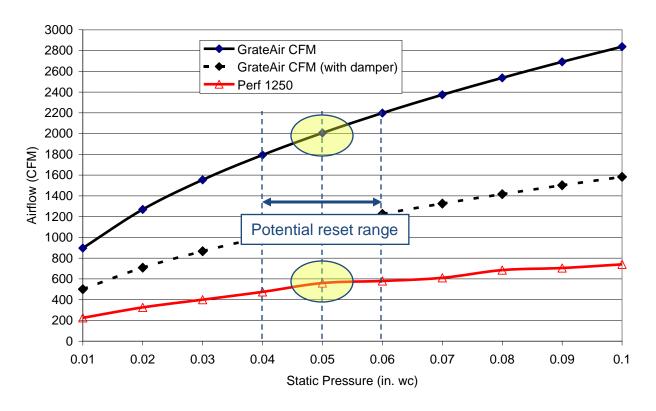
	Vaisala Probe			CRAC Unit Panel				
	Temp	RH	Tdp	Temp	RH	Tdp	Mode	
AC 005	84.0	27.5	47.0	76	32.0	44.1	Coolina	
AC 006	81.8	28.5	46.1	55	51.0	37.2	Cooling & Dehumidification	
AC 007	72.8	38.5	46.1	70	47.0	48.9	Coolina	
AC 008	80.0	31.5	47.2	74	43.0	50.2	Cooling & Humidification	
AC 010	77.5	32.8	46.1	68	45.0	45.9	Coolina	
AC 011	78.9	31.4	46.1	70	43.0	46.6	Cooling & Humidification	
Min	72.8	27.5	46.1	55.0	32.0	37.2		
Max	84.0	38.5	47.2	76.0	51.0	50.2		
Avg	79.2	31.7	46.4	68.8	43.5	45.5		

Airflow controls underfloor

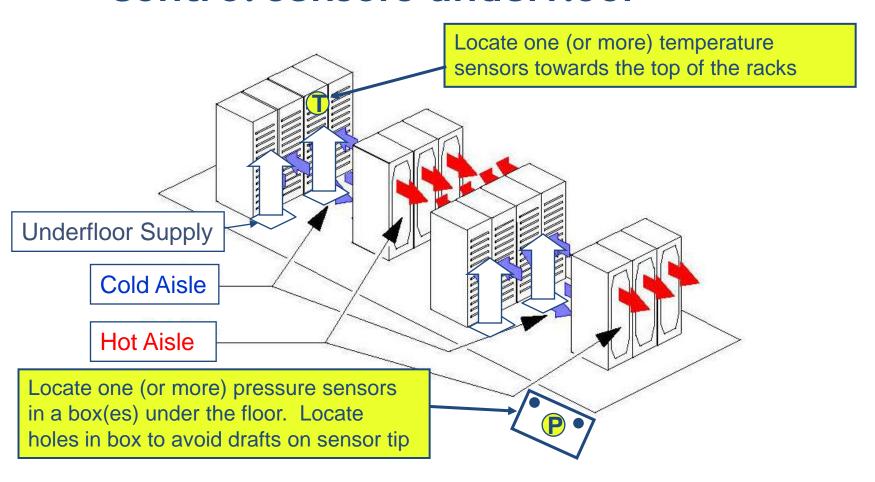
- All supply fans controlled to same speed.
- Set speed to maintain differential pressure setpoint under floor (can use multiple sensors).
- Reset differential pressure setpoint by highest rack temperature (slow acting loop).

Reset of floor pressure to satisfy racks

Tate Perforated Floor Tile Performance vs. Underfloor Pressure



Control sensors underfloor

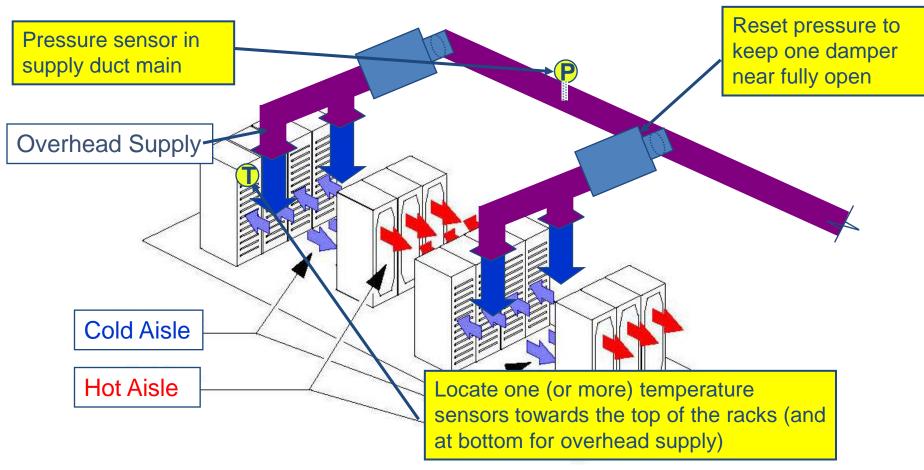


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Airflow controls overhead

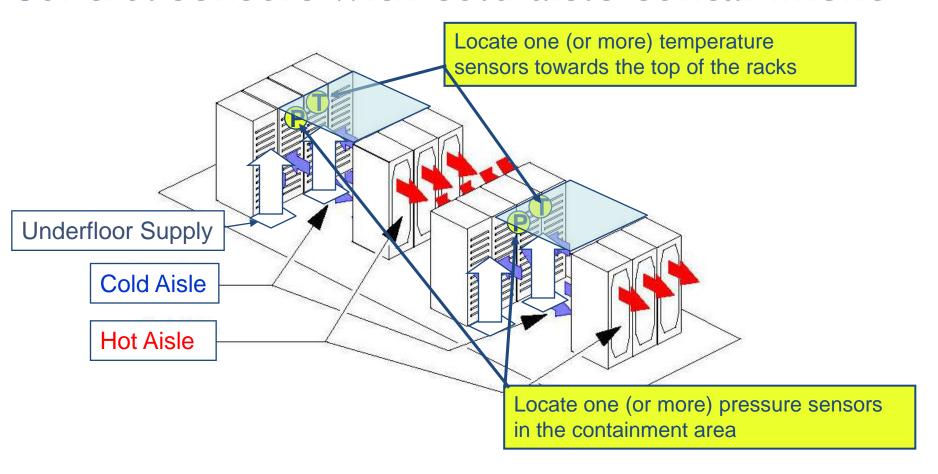
- All headered supply fans controlled to same speed
- Set speed to maintain pressure in supply header
- Control dampers to maintain racks at temperature
- Reset pressure setpoint to keep most open damper at or near fully open

Control sensors overhead



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Control sensors with cold aisle containment



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Best practice controls

- Use high quality sensors (not the ones that come with the CRAC/H units!).
- Temperature sensors should be located in the supply air stream not the return
- If used, locate the humidity sensor in the data center floor (not in the unit return).
- Reset temp and pressure by demand at racks.
- Avoid humidity controls if possible, if necessary provide it on MUA unit.
- Provide CRAC/H or AHUs with variable speed fans and control all fans in parallel to same speed.
- Used advanced whole system metrics to track system performance.
- Commission the controls thoroughly.



Electrical Systems Efficiency

Bill Tschudi, PE



Electrical systems efficiency

- Electrical distribution systems
- Lighting
- Standby generation

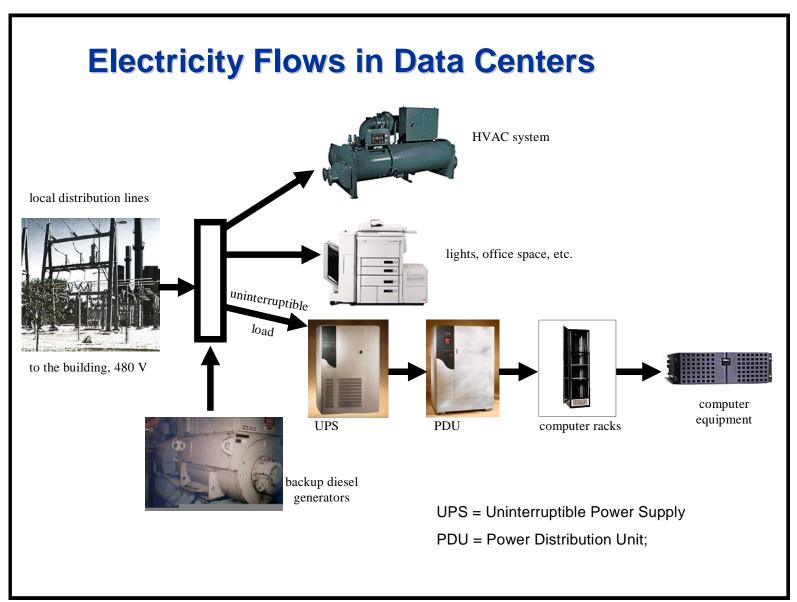
• On-site generation

Root causes of electrical system inefficiency

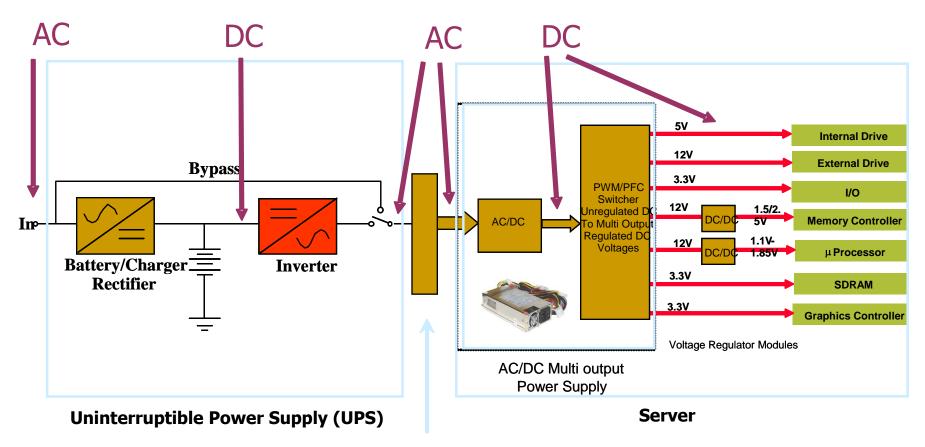
- Physical infrastructure is typically OVERSIZED for most of its life
- Power requirements are initially greatly OVERSTATED
- Legacy INEFFICIENT equipment is incorporated
- IT equipment is on and not doing anything
- Multiple POWER CONVERSIONS each conversion loses some power and creates heat
- Power conversion efficiency is not optimized

Electrical distribution 101

- Every power conversion (AC-DC, DC-AC, AC-AC) loses some power and creates heat
- Distributing higher voltage is more efficient and saves capital cost (wire size is smaller)
- Uninterruptible power supplies (UPS's) efficiency varies
- Power supplies in IT equipment efficiency varies



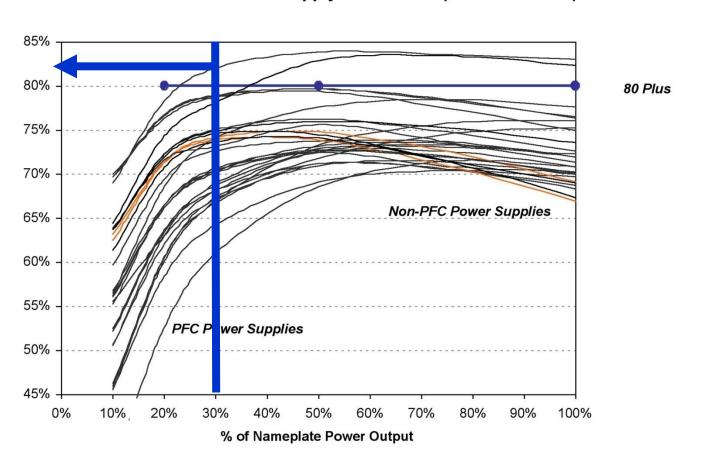
From utility power to the chip -multiple electrical power conversions



Power Distribution Unit (PDU)

Measured power supply efficiency

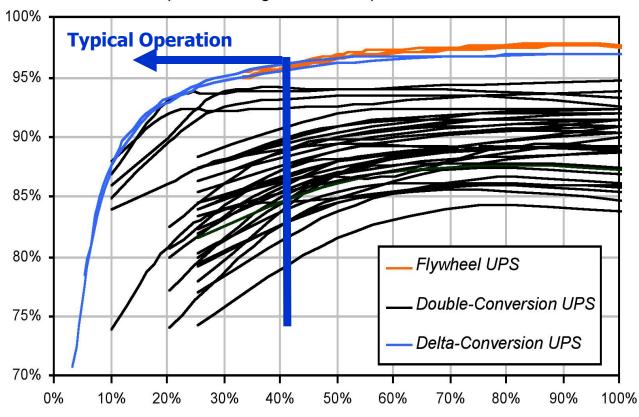
Measured Server Power Supply Efficiencies (all form factors)



UPS factory measurements

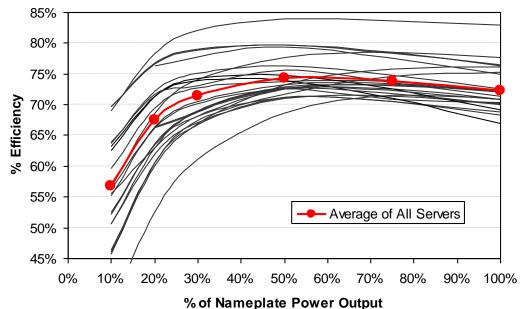
Factory Measurements of UPS Efficiency

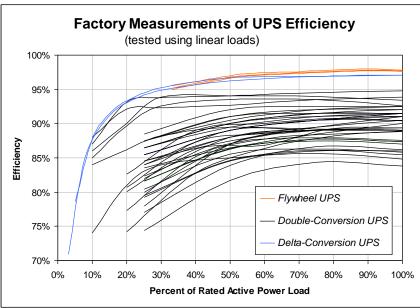
(tested using linear loads)



Electrical power conversion efficiency

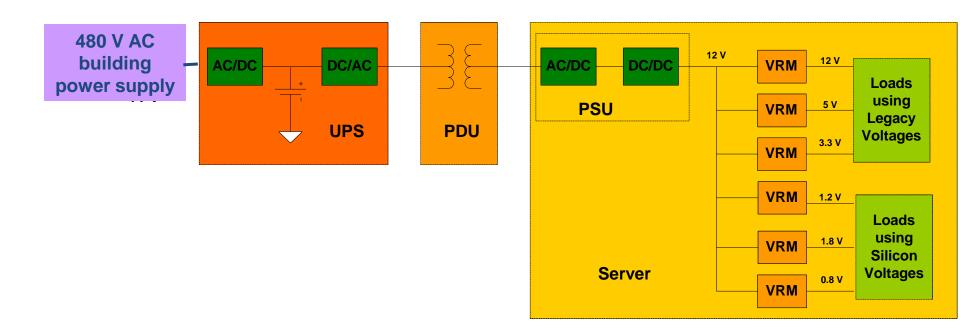
varies





LBNL DC power demonstration

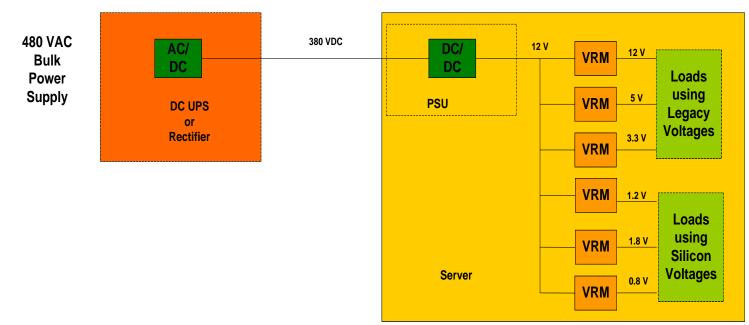
"Today's" AC distribution



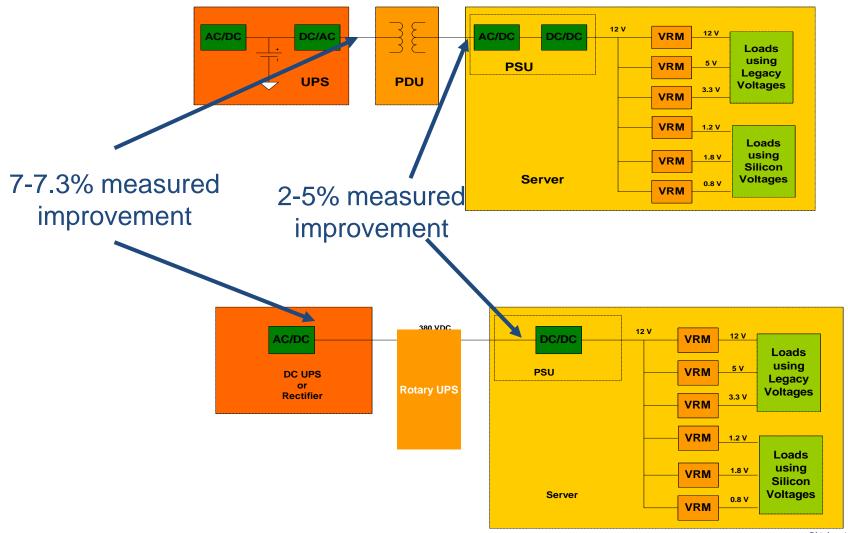
DC power distribution

Eliminates several stages of power conversion.

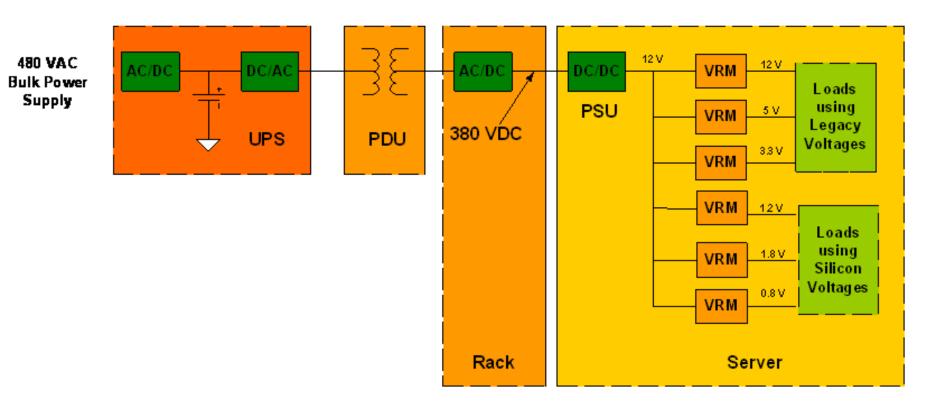
Facility-Level DC Distribution



AC system loss compared to DC



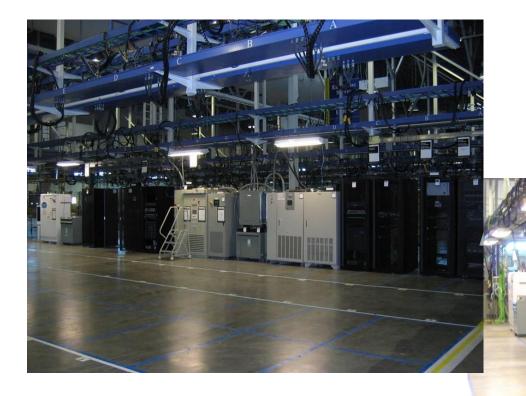
Rack-level DC distribution



Other benefits of 380 V. DC distribution

- Easy to tie in renewable sources
- Direct use in variable speed drives
- Use of DC lighting
- Minimize power quality issues
- Reduced HVAC
- Less capital cost
- Potential for world wide standard

DC demonstration



Video available through LBL website

Redundancy

- Understand what redundancy costs is it worth it?
- Different strategies have different energy penalties (e.g. 2N vs. N+1)
- Its possible to more fully load UPS systems and achieve desired redundancy
- Redundancy in electrical distribution always puts you down the efficiency curve
- Consider other options

Electrical systems sizing

 IT Design Load typically was historically based on IT Nameplate plus future growth

Problem - actual IT loads are <25% of nameplate

IT load was determined on a Watts/sf basis

Problem -IT loads are now concentrated

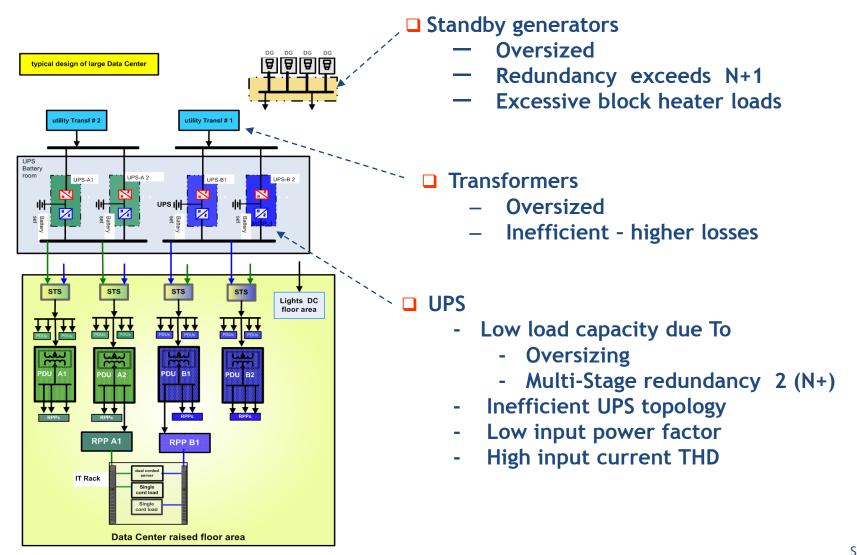
UPS systems are sized for IT load plus 20-50%

Problem - load was already oversized by factor of 4

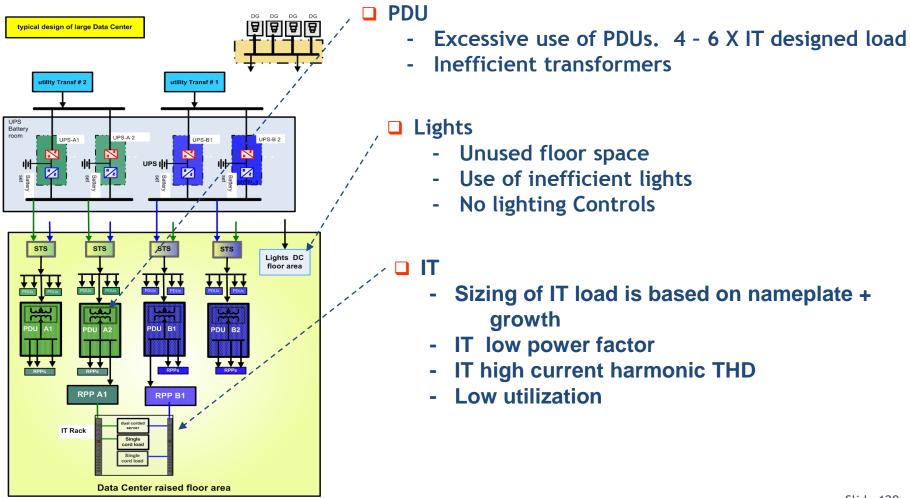
Standby generators are sized for UPS load x2 or more

Problem - block heaters

Infrastructure inefficiency



Infrastructure inefficiency



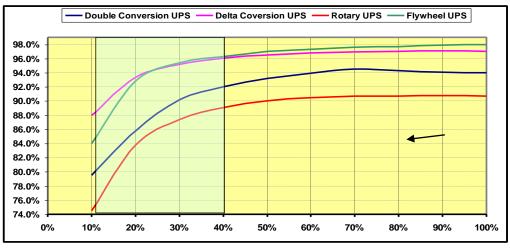
Managing UPS efficiency:

UPS sizing and loading can significantly affect UPS efficiency:

- Maximize UPS load capacity
- Specify UPS system that has higher efficiency at 10 - 40% load capacity
- Specify efficient UPS topology
- Consider modular UPS (an option to maximize UPS load capacity)

Managing UPS load capacity

Example: 10% difference in UPS efficiency per 1000 kW IT load results in approximately 900 MWhr of Energy saving per year and approx \$400K of energy saving over 5 years.

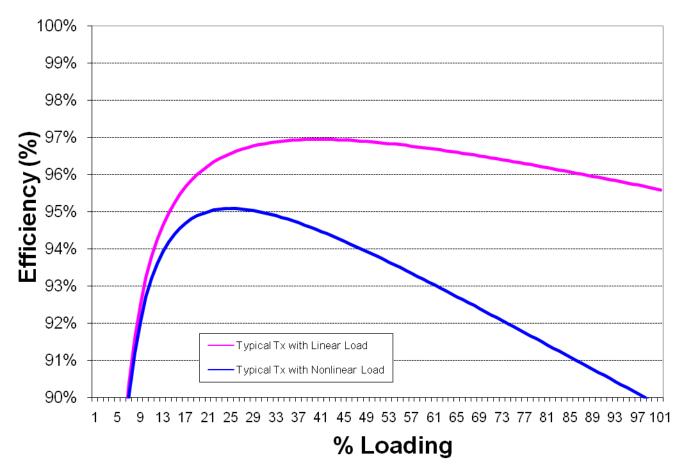


Most UPS units in N or N+X configuration operate at 10% to 40% load capacity

Transformers and PDUs

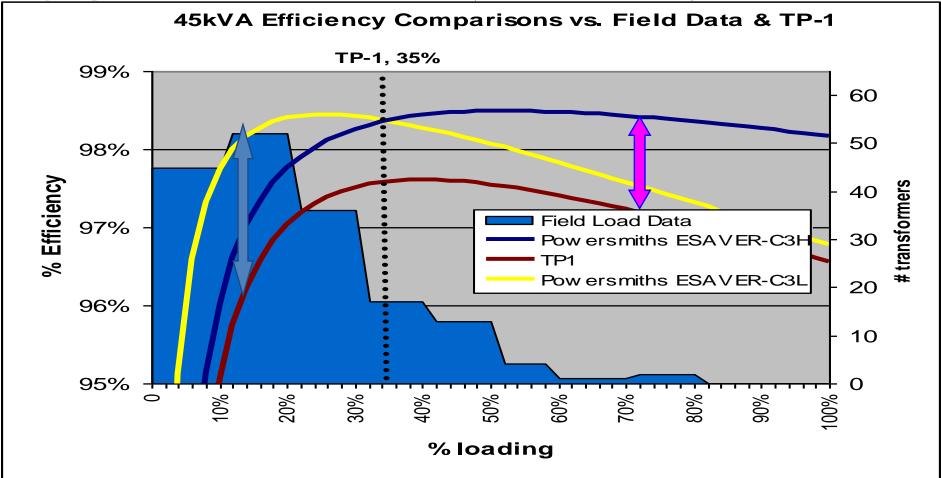
- Specify high efficiency transformers
- Install low voltage (LV) transformers outside the raised floor area
- Reduce number of PDUs (with built-in transformer) inside the data center

Typical 112.5kVA nonlinear UL listed transformer



Significant variation in efficiency over load range

High performance vs. TP1 (EPACT 2005) transformer



ESAVER C3L -> Light Load optimized, C3H -> Heavy Load optimized

Data center lighting

- Lights are on and nobody's home
 - Switch off lights in unused/unoccupied areas or rooms (UPS, Battery, S/Gear, etc)
 - Lighting controls such as occupancy sensors are well proven
- Small relative benefit but easy to accomplish also saves HVAC energy
- Use energy efficient lights -Replace older coil/core Ballasts type with new efficient electronic ones
- Lights should be located over the aisles
- DC lighting would compliment DC distribution

Standby generation loss

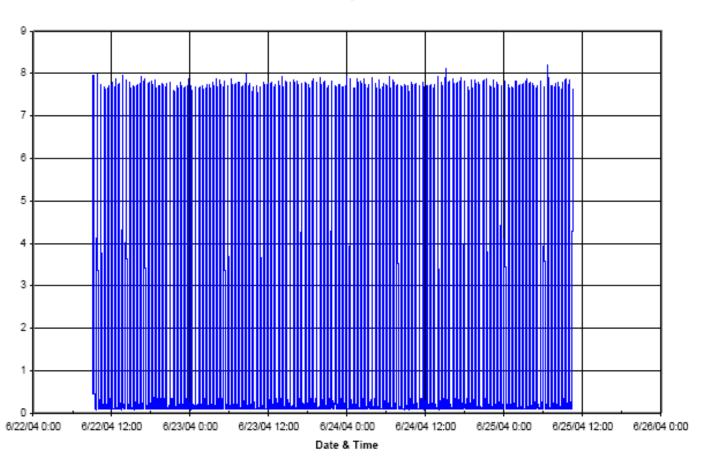
- Several load sources
 - Heaters
 - Battery chargers
 - Transfer switches
 - Fuel management systems
- Opportunity may be to reduce or eliminate heating, batteries, and chargers



- Heaters (many operating hours) use more electricity than the generator will ever produce (few operating hours)
 - Check with the emergency generator manufacturer on how to reduce the overall energy consumption of block heaters (hot water jacket(s) HWJ), i.e. temperature control
- Right-sizing of stand-by generator
- Maintain N+1 redundancy

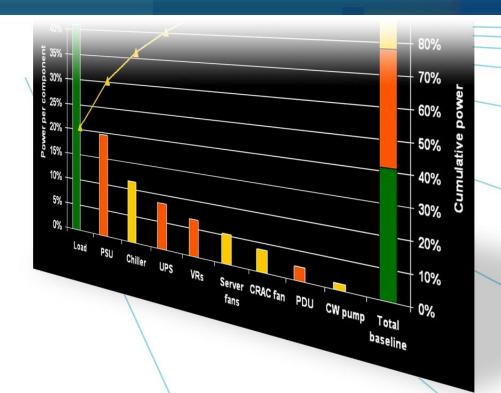
Standby generator heater

Generator Standby Power Loss



Electrical system take aways

- Distributing higher voltage (AC or DC) is more efficient
- Power conversions hurt efficiency
- Highly efficient UPS systems, transformers, and power supplies in IT equipment should be specified
- Lighting energy use is small but an easy opportunity (efficiency and controls)
- Redundancy choices affect efficiency
- Standby generation losses can be minimized
- On-site generation can improve reliability and efficiency
- Consider alternative energy sources



Assessment Tools and Protocols

Bill Tschudi, PE





Online profiling tool

INPUTS

- Description
- Utility bill data
- System information
 - IT
 - Cooling
 - Power
 - On-site gen



a Center Energy Profiler, or DC Pro, is an online software tool provided by the U.S. nent of Energy to help industries worldwide identify how energy is being purchased insumed by their data center(s) and also identify potential energy and cost savings. It is designed so that the user can complete a data center profile in about an hour. The online tutorial will explain what data center information you need to complete a DC case. When you complete a DC Pro case you are provided with a customized, printable ort that shows the details of energy purchases for your data center, how energy is insumed by your data center, potential cost and energy savings, comparison of your data enter energy utilization versus other data centers, and a list of next steps that you can sollow to get you started saving energy.

The current version of DC Pro is 1.1.1, released 12/12/2006.

Industrial Technologies Program Home | EERE Home | U.S. Department of Webmaster | Web Site Policies | Security & Privacy | USA.gov

DC Pro Reso

• Online

Checkli

that you

tutorial.

OUTPUTS

- Overall efficiency (DCiE)
- End-use breakout
- Potential areas for energy efficiency improvement
- Overall energy use reduction potential

DOE tool suite: DC Pro

- Profiling Tool: profiling and tracking
 - Establish DCIE baseline and efficiency potential (few hours effort)
 - Document actions taken
 - Track progress in DCiE over time
- Assessment tools: more in-depth site assessments
 - Suite of tools to address major sub-systems
 - Provides savings for efficiency actions
 - ~2 week effort (including site visit)

DC Pro tools

High Level Profiling Tool

- Overall energy performance (baseline) of data center
- Performance of systems (infrastructure & IT) compared to benchmarks
- Prioritized list of energy efficiency actions and their savings, in terms of energy cost (\$), source energy (Btu), and carbon emissions (Mtons)
- Points to more detailed system tools



IT Module

- Servers
- Storage & networking
- Software



Cooling

- Air handlers/ conditioners
- Chillers, pumps, fans
- Free cooling



Air Management

- hot cold separation
- environmental conditions



Electrical Systems

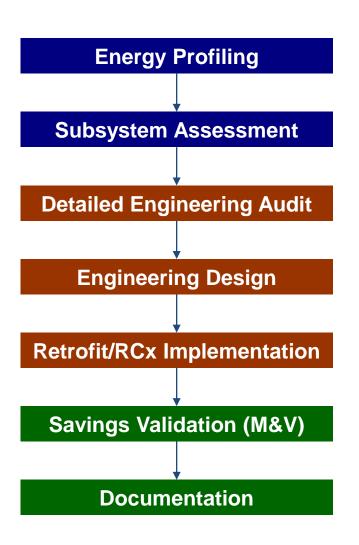
- UPS
- PDU
- Transformers
- Lighting
- Standby gen.



On-Site Gen

- Renewables
- use of waste heat

Steps to saving energy:



- Assessments conducted by owners and engineering firms using DOE tools
- Tools provide uniform metrics and approach

 Audits, design and implementation by engineering firms and contractors

- M&V by site personnel and eng firms
- DOE tools used to document results, track performance improvements, and disseminate best practices

Getting started with an assessment

Visit:

http://hightech.lbl.gov/dc-assessment-tools.html

- Assessment process description
- Assessment worksheet
- Standard report template
- Master list of actions
- Link to DC Pro profiling tool
- Electrical systems tool (Beta spreadsheet version)

DC Pro profiling tool demonstration

www.eere.energy.gov/datacenters

Assessment worksheet

- List of metrics and features
 - Priorities for metrics
 - Data required
- Data collection template
- List of actions

Data Center Assessment Inputs: Features and Metrics DRAFT 1-24-08

Notes:

- 1. Each assessment area has two types of inputs: features and metrics
- 2. The features checklist can be used for stage 1 assessment (prior to site visit), and to prioritize metrics for stage 2 assessment
- 3. Input fields are shaded in blue defaults are provided for priorities
- 4. Priority levels for metrics: 1 Must have; 2 Important, subject to ease of data collection; 3 collect only if easily available

1. Overall Energy Management				
Has an audit or commissioning been conducte				
Is there a written energy management plan?				
Are there staff with explicit energy managemen				
What is the redundancy level for Electrical syst				
What is the redundancy level for HVAC system				
What is the current usage factor? (% of space?	?)			
Metrics	Unit	Data Required	Priority	Value
Overall Energy Effectiveness	-	IT Equipment Energy Use	1	
(IT energy use / total energy use)		Total DC Energy Use (Site)		
Site Energy Use Intensity	Site BTU/sf-yr	Total DC Energy Use (Site)	2	
Source Energy Use Intensity	Source BTU/sf-yr	DC Floor Area Total DC Energy Use (Source)	3	
location Emolgy doe intensity	000100 210701 91	DC Floor Area	Ü	
Purchased Energy Cost Intensity	Energy \$/sf-yr	Total DC Energy Cost	2	
		DC Floor Area		
Peak Electrical Load Intensity	Peak W/sf	Total DC Peak Elec Demand DC Floor Area	2	
2. Environmental Conditions				
What are the temperature setpoints (specify ra	nge)?			
What are the humidity setpoints (specify range	-			
Recommended and allowable intake temperate		cify ranges)?		
Where are temperature and humidity sensors I				
Do CRAC/CRAH units have centralized or dist				
Are there humidity controls and does the data	center need humidity c	ontrol?		
Are there procedures and personnel/cable gro	unding equipment to pr	event ESD?		
Are unit controls fighting each other (for examp	ole, simultaneously hun	nidifying and dehumidifying)?		
Does system have capability of taking slope ar	nd offset for sensor rec	alibration?		
Metrics	Unit	Data Required	Priority	Value
Ratio Max Density to Average Heat Density	None	Max Heat Density	2	
	None	Average Heat Density		
Actual Dew-Point Temperature	F -	Data Center Dewpoint Temperature	1	
Climate Data Temperature and humidity sensor calibration	Slope and offset	TMY/TRY/WYEC data Reference sensor reading	1	
remperature and numberly sensor calibration	Slope and offset	Reference sensor reading	ı	
3. Air Management, CRAC/CRAH/AHU				
How many CRAC/CRAH/AHUs are there? Ide	ntify which operate und	der normal conditions and which are		
standby.				
For each CRAC/CRAH/AHU collect nameplate capacity and design conditions.	data for unit, for each	motor and submittal data identifying		
What is the clear ceiling in feet (slab to slab mi				
Is there a ceiling return plenum? If yes, what is				
Is there a floor supply plenum (raised floor)? If				
What is the estimated floor leakage in percent				
Where are cables and pipes located?				
are capies and pipes located!				

Example "DC Pro" recommendations

List of Actions (for Electric Distribution System)

- Avoid lightly loaded UPS systems
- Use high efficiency MV and LV transformers
- Reduce the number of transformers upstream and downstream of the UPS
- Locate transformers outside the data center
- Use 480 V instead of 208 V static switches (STS)
- Specify high-efficiency power supplies
- Eliminate redundant power supplies
- Supply DC voltage to IT rack



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Data confidentiality

- All input data is treated as confidential
- Data in benchmarking charts are "anonymized" with random facility ID numbers
- Data is saved to a secure database server and can not be accessed by the general public

Contact information

DOE Data Center Program

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DOE Industrial Technologies Program

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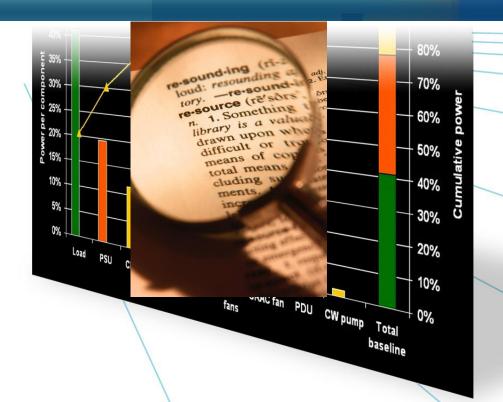
DC Pro Tool Suite

Paul Mathew

Lawrence Berkeley National Laboratory

510-486-5116

pamathew@lbl.gov





Resources

Bill Tschudi, PE



Links to get started

DOE Website: Sign up to stay up to date on new developments www.eere.energy.gov/datacenters

Lawrence Berkeley National Laboratory (LBNL)

http://hightech.lbl.gov/datacenters/

LBNL Best Practices Guidelines (cooling, power, IT systems)

http://hightech.lbl.gov/datacenters-bpg/

ASHRAE Data Center technical guidebooks

http://tc99.ashraetcs.org/

The Green Grid Association: White papers on metrics

http://www.thegreengrid.org/gg_content/

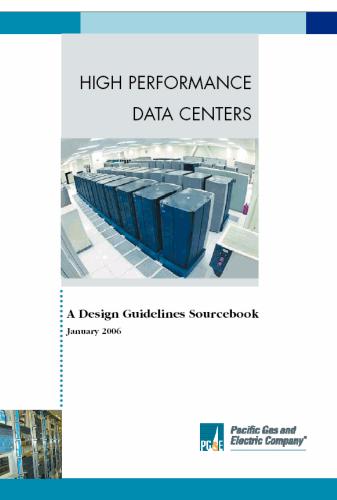
Energy Star® Program

http://www.energystar.gov/index.cfm?c=prod_development.server_efficiency

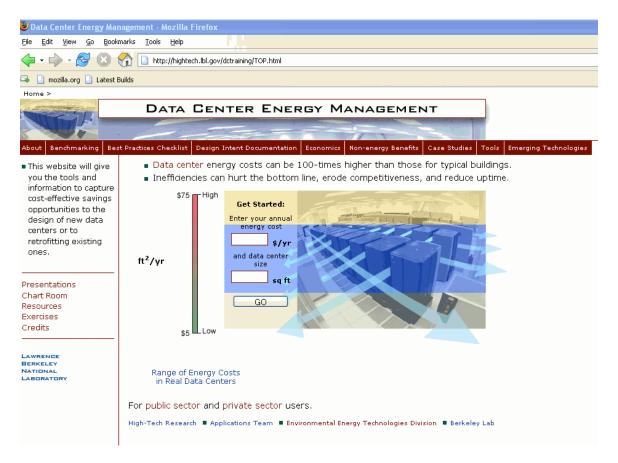
Uptime Institute white papers www.uptimeinstitute.org

Design guidelines are available

- Design Guides were developed based upon observed best practices
- Guides are available through LBNL website



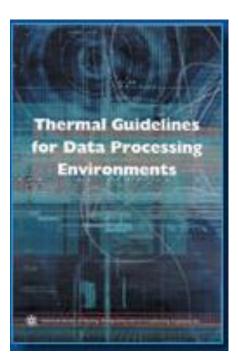
Web based training resource

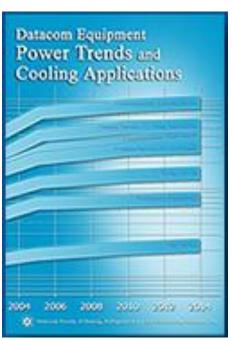


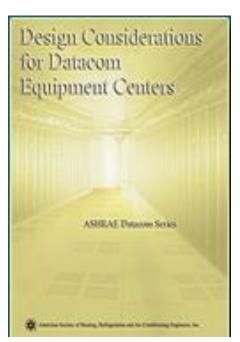
http://hightech.lbl.gov/dctraining/TOP.html

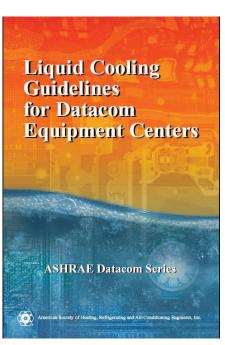
ASHRAE guidelines

six books published—more in preparation









ASHRAE, Thermal Guidelines for Data Processing Environments, 2004, Datacom Equipment Power Trends and Cooling Applications, 2005, Design Considerations for Datacom Equipment Centers, 2005, Liquid Cooling Guidelines for Datacom Equipment Centers, 2006, © American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc., www.ashrae.org

Order from http://tc99.ashraetcs.org/

ASHRAE resources

- ASHRAE (http://www.ashrae.org)
 - Technical Committee (TC) 9.9 Mission Critical Facilities http://tc99.ashraetcs.org/
 - Additional Guidelines in Development
 - Contamination

IT power supply resources

Server System Infrastructure

Managing Component Interfaces



- www.ssiforums.org
- www.80plus.org

Other resources

- Electrostatic Discharge Association (<u>http://www.esda.org/</u>)
- Uptime Institute (http://www.upsite.com/TUIpages/tuihome.html)
- Green Grid (http://www.thegreengrid.org/home)
- Chilled Water Plant Resources
 - PG&E CoolTools™ Chilled Water Plant Design Guide (http://taylor-engineering.com/publications/design_guides.shtml)
 - ASHRAE Journal article, "Balancing Variable Flow Hydronic Systems" and other CHW articles on TE website at http://www.taylor-engineering.com/publications/articles.shtml

Contact information:

Bill Tschudi, P.E.

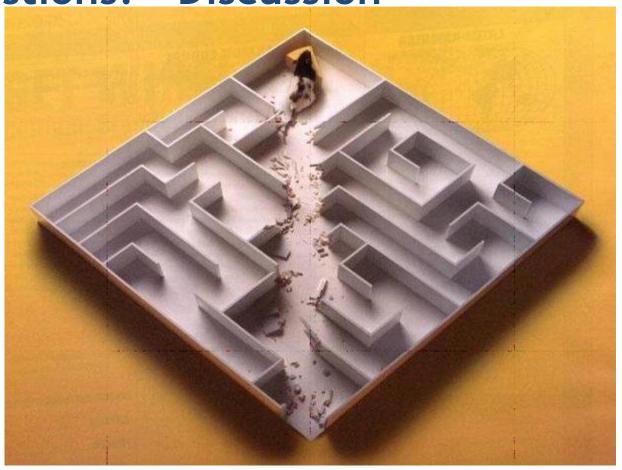
Lawrence Berkeley National Laboratory Applications Team MS 90-3011 Lawrence Berkeley National Laboratory Berkeley, CA 94720

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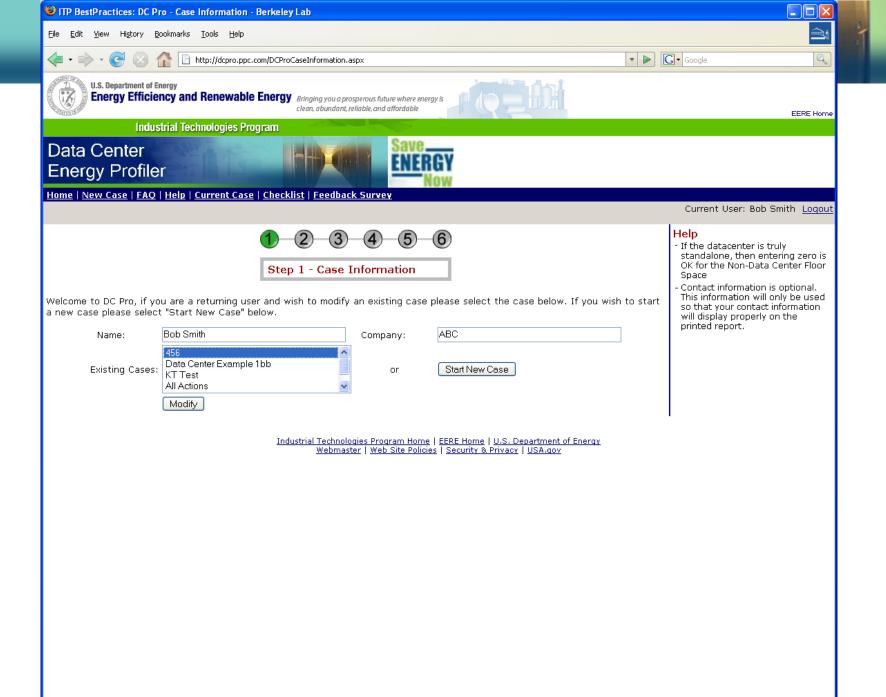
Questions? - Discussion

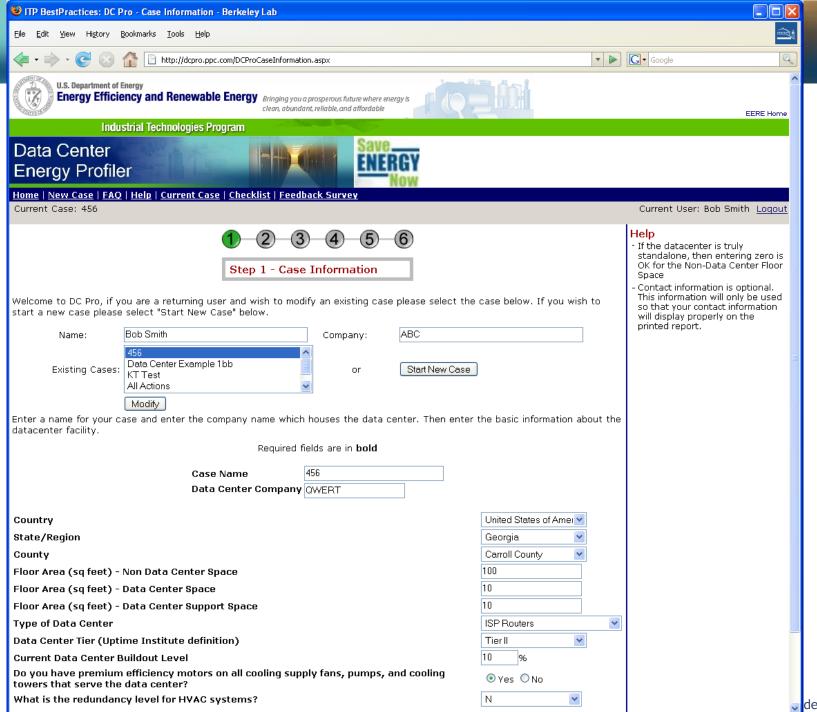


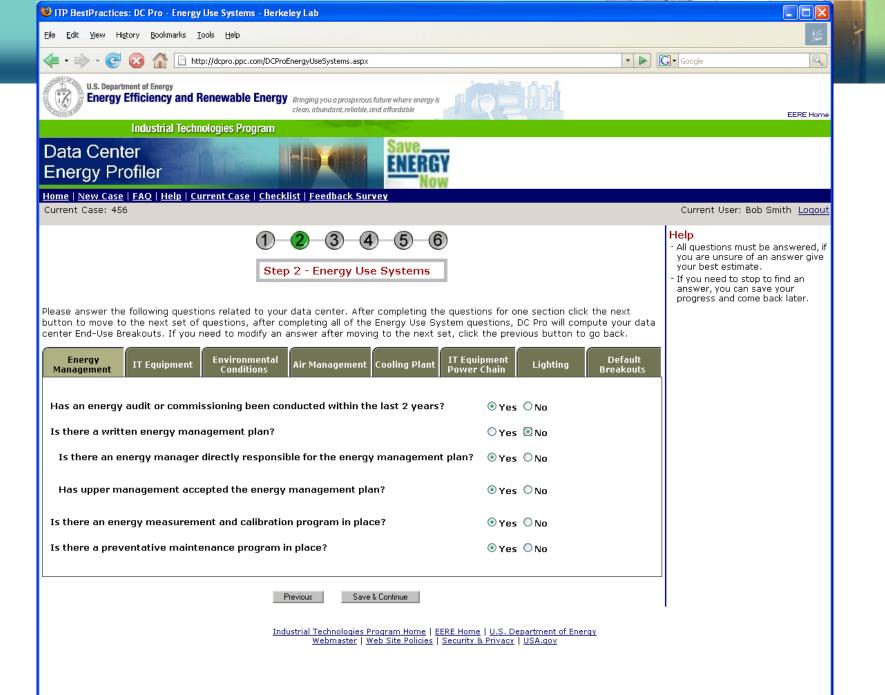
Thank you for attending

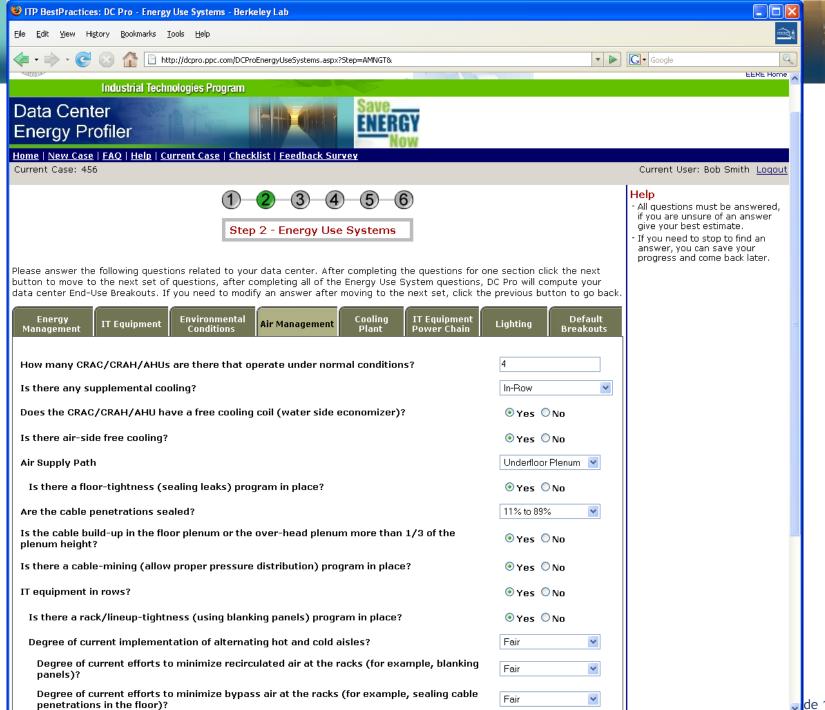


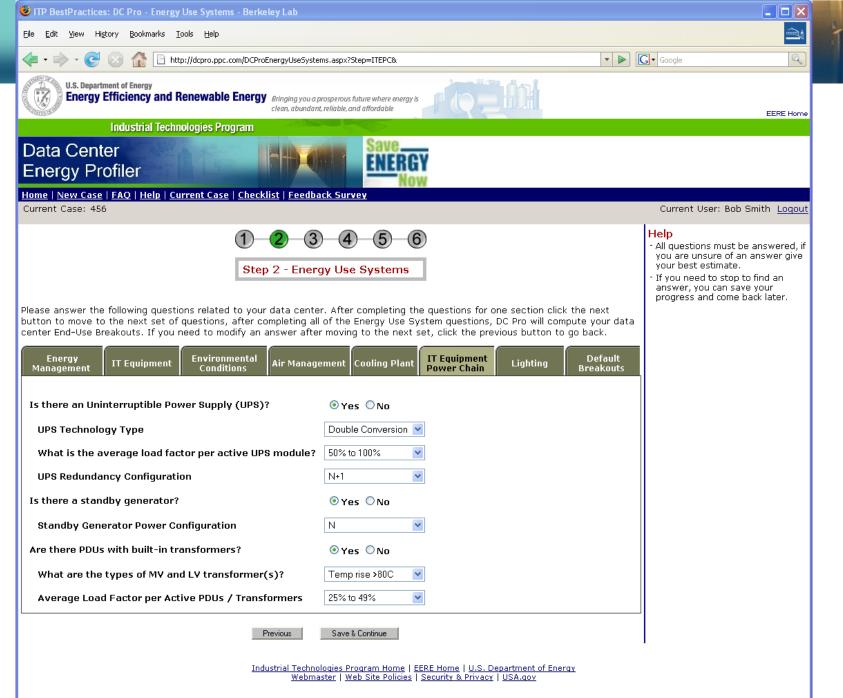
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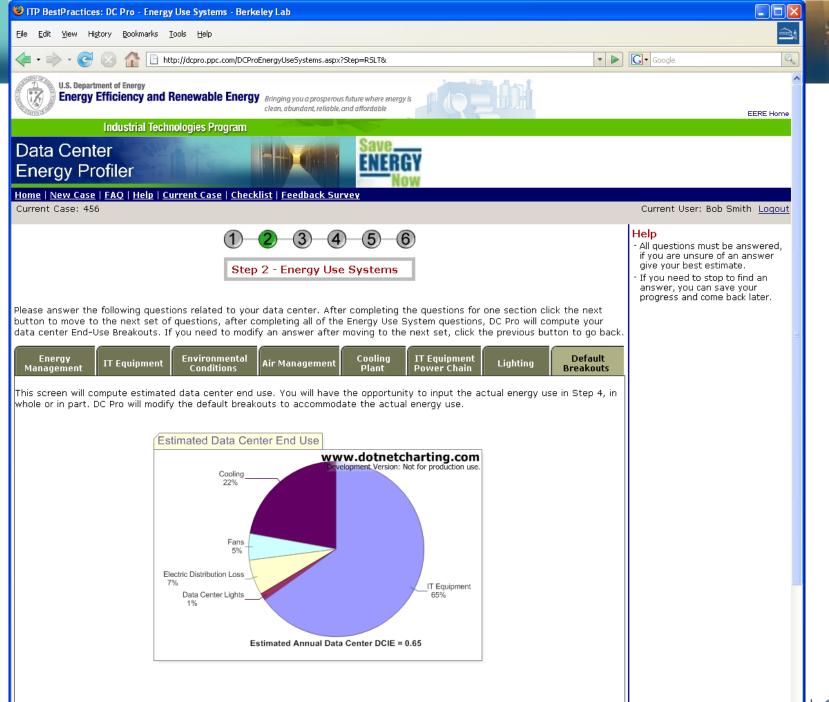


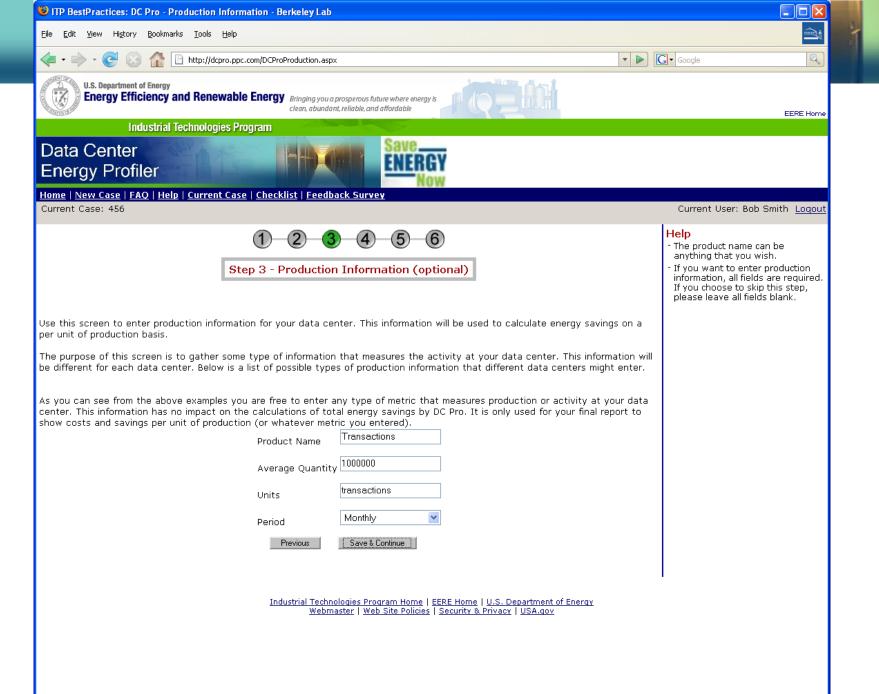


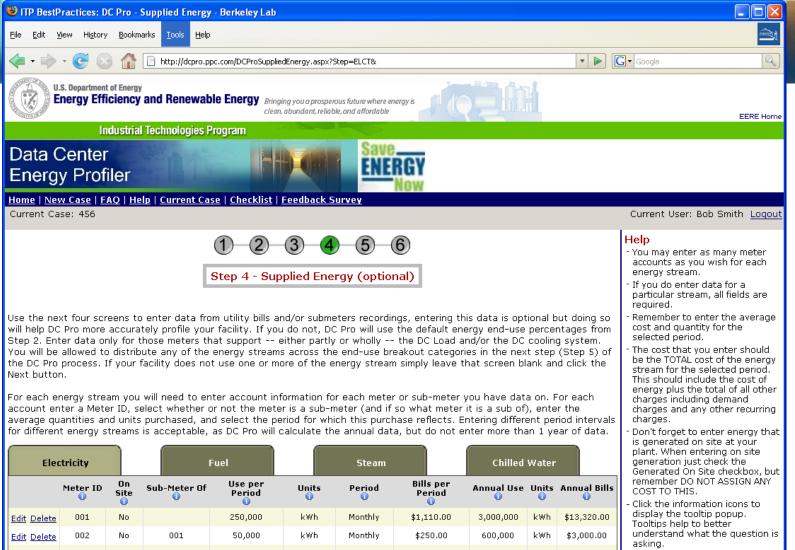






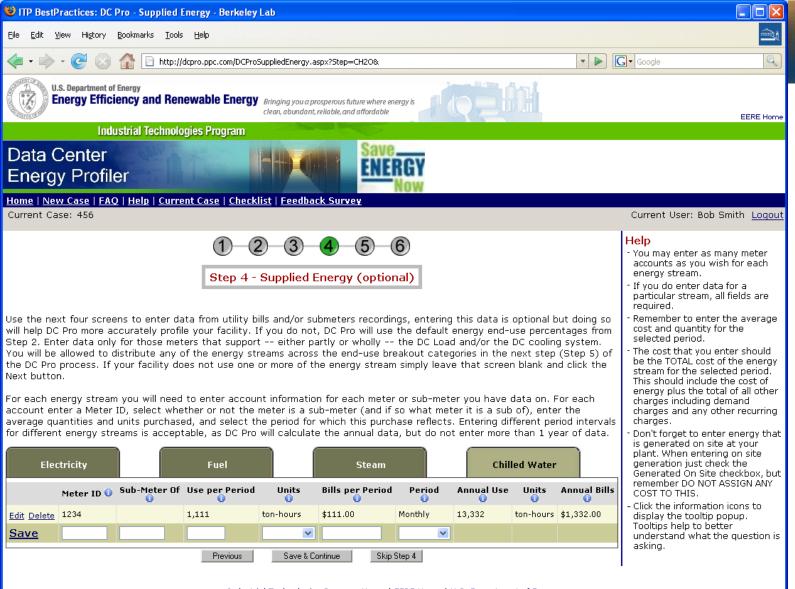






kWh Edit Delete 213 No 25,555 Monthly: \$12,345.00 306,660 kWh \$148,140.00 Save ٧ Previous Save & Continue Skip Step 4

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Energy Profiler





Home | New Case | FAQ | Help | Current Case | Checklist | Feedback Survey

Current Case: 456



Step 5 - Energy Use Distribution (optional)

Use these screens to allocate the annual energy use for each meter identified in Step 4 across the Energy End-Use Breakout Categories.

If you do not know what the allocations are for a given meter, it is OK to skip this screen or enter estimates. All of the energy use for a given meter does not have to be allocated to the breakout categories. If the meter serves more than just the data center, it is OK to leave a portion of the energy in the Remainder column.

NOTE: DC Pro provides default percentages for you based on the information entered in Step 2. You may use these default percentages if you are unsure of the actual percentages that each energy use system uses. However, for more accurate results you should estimate your actual percentages and enter them in the boxes below.

Electricit	y		Fuel			Steam	,		Chilled Wa	nter		Sumr	nary	
Total Annual		Site Energy End-Use Breakout Categories Recalculate												
Site Energy Use	IT Lo	ad 🛈	Ligh	ıts 🛈	Distri	bution	Fan	s 🛈			Use Relate	d to	Remain (Non-De Center L	ata
kWh/yr	kWh/yr	9/6	kWh/yr	9/6	kWh/yr	9/6	kWh/yr	9/0	kWh/yr	9/6	kWh/yr	9/6	kWh/yr	9/6
3,000,000	1700000	57%	90000	3%	350000	12%	600000	20%	90000	3%	2,830,000.0	94%	170,000	6%
600,000	400000	67%	60000	10%	90000	15%	18000	3%	12000	2%	580,000.0	97%	20,000	3%
306,660	153330	50%	91998	30%	0	0%	9199.8	3%	9199.8	3%	263,727.6	86%	42,932.4	14%
	2,253,330	58%	241,998	6%	440,000	11%	627,199.8	16%	111,199.8	3%	3,673,727.6	94%	232,932.4	6%
all the ity ted with akout ries being y the data	Yes 💌		Yes	V	Yes	V	Yes		Yes 💌					
	Total Annual Site Energy Use kWh/yr 3,000,000 600,000 306,660 all the ity ted with akout ies being the data	Annual Site Energy Use Use 17 Lo 1700000 1700000 1700000 1700000 153330 2,253,330 all the sity ted with akout ies being the data	Total Annual Site Energy Use IT Load kWh/yr kWh/yr % 3,000,000 1700000 57% 600,000 400000 67% 306,660 153330 50% 2,253,330 58% all the ity ted with akout ies being the data	Total Annual Site Energy Use IT Load Ligh kwh/yr kwh/yr % kwh/yr 3,000,000 1700000 57% 90000 600,000 400000 67% 60000 306,660 153330 50% 91998 2,253,330 58% 241,998 all the ity ted with akout ies being the data	Total Annual Site Energy Use IT Load Lights Site Energy Use En	Total Annual Site Energy Site Energy Use IT Load Lights Lights Lights Lights Lights Lights Lights Loss kWh/yr kWh/yr	Total Annual Site Energy End-Use IT Load	Total Annual Site Energy End-Use Breakout Control Site Energy Use	Total Annual Site Energy End-Use Breakout Categori	Total Annual Site Energy End-Use Breakout Categories	Total Annual Site Energy End-Use Breakout Categories Recalculate	Total Annual Site Energy End-Use Breakout Categories	Total Annual Site Energy End-Use Breakout Categories Recalculate	Total Annual Site Energy End-Use Breakout Categories Recalculate

Help

Current User: Bob Smith Logout

- Please enter a value for each meter or sub-meter. If the meter or sub-meter does not use any energy from a given category, enter zero.
- The total annual energy use for each meter are the values calculated in Step 4. If you notice a problem with a meter or need to modify one, go back to Step 4 by clicking the circle on the top of this page.
- The percentages in the "Energy Use Related to Data Center" and "Remainder" column for a given meter MUST equal 100%, DC Pro will not let you move onto the next page if they do not.
- You must select "Yes"or "No" in the final row before proceeding to the next energy type. Select "Yes" if there is no additional energy being used by the data center for a given breakout category, Select "No" if there is



Open the Report in PDF

This is your customized DC Pro Summary Report. The report is broken into five basic sections. If you wish to go back and edit any of your values or add more dat page to navigate to the desired screen.

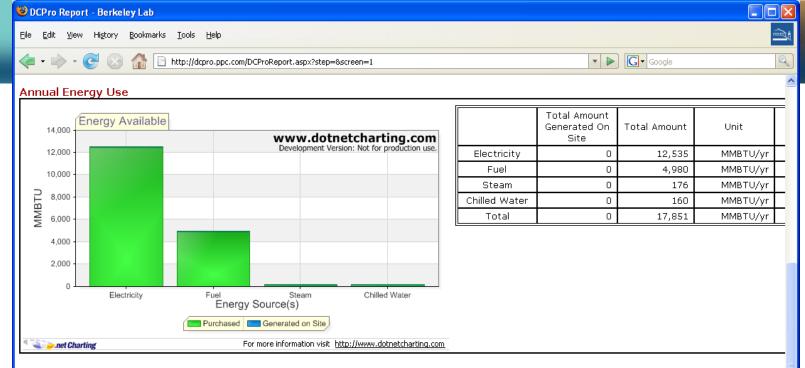
- 1. Case Information your basic case information including energy consumption and savings on a per unit of production basis.
- 2. Annual Energy Use a summary of your data center's annual energy purchases and consumption broken down by energy category.
- 3. Potential Annual Energy Savings an estimation of potential annual energy savings for your data center's energy use systems displayed in MMBtu and dollar
- 4. Potential Annual CO2 Savings an estimation of the potential annual reduction of CO2 emissions.
- 5. Suggested Next Steps a customized list of suggested next steps for you to take to realize potential energy and cost savings.

Case Information

Case Name	456			
Case Maille	730			
Name	Bob Smith			
Email	bsmith@abc.com			
Company	ABC			
Data Center Company	QWERT			
County	Carroll County			
State	Georgia			

Annual Energy Use

14,000 Energy Available	www.dotnetcharting.com		Total Amount Generated On Site	Total Amount	Unit
12,000	Development Version: Not for production use.	Electricity	0	12,535	MMBTU/yr
10,000		Fuel	0	4,980	MMBTU/yr



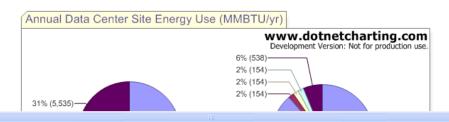
Potential Annual Energy Savings

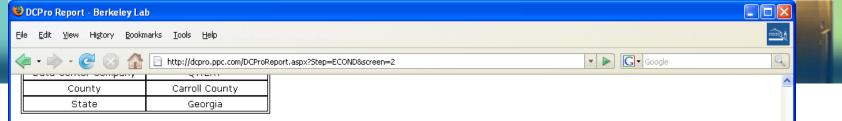
Suggested Next Steps

The following chart and data table summarize your data center's potential annual energy savings by breakout catergory.

NOTE: The energy and money savings listed below are only estimates based on the data you entered and the estimated costs associated with the data center su

		Curren	t Energy Use		Dr	tential F	nergy Use		
Breakout Category	Site Energy		Source Energy		Site Energy		Source Ener	gy	Potential Sa
	MMBTU/yr	%	MMBTU/yr	%	MMBTU/yr	%	MMBTU/yr	%	MMBTU/yr
IT Equipment	7,689	43%	25,872	54%	7,689	88%	25,872	88%	0
Data Center Lights	826	5%	2,779	6%	154	2%	517	2%	672
Electric Distribution Losses	1,501	8%	5,052	11%	154	2%	517	2%	984
Fans	2,140	12%	7,201	15%	154	2%	517	2%	1,623
Cooling	5,535	31%	7,203	15%	538	6%	1,811	6%	3,724
Total	17,691	100%	48,107	100%	8,688	100%	29,236	100%	7,003
DCIE		0.43		0.54		0.88		0.88	





Suggested Next Steps

Potential Annual Savings

	nergy agement IT Equipment	Environmental Conditions	Air Management	Cooling Plant	IT Equipment Power Chain	Lighting	Global Action			
EC.A.1	Consider Air-Management measures	A low air temperature ri range suggest air mana temperature is due to n will indicate if correctiv	gement problems. A ecirculation air. Estir	low return temperat mating the Return Te	ture is due to by-pa	ss air and an eleva	ted return			
EC.A.2	Consider increasing the supply temperature	A low supply temperature makes the chiller system less efficient and limits the utilization of economizers. Enclosed esupply architectures allow the highest supply temperatures (near the upper end of the recommended intake temperature range) since mixing of hot and cold air is minimized. In contrast, the supply temperature in open architectures is often dictated by the hottest intake temperature.								
EC.A.4	Place temperature/humidity sensors so they mimic the IT equipment intake conditions IT equipment and are not located at the IT equipment intakes. The condition of the air supplied by the cooling system is often significantly different by the time it reaches the IT equipment intakes. It is usually not practically to provide sensors at the intake of every piece of IT equipment, but a few representative locations can be selected. Adjusting the cooling system sensor location in order to provide the air condition that is needed at the IT equipment intake often results in more efficient operation.									
EC.A.5	Temperature sensors generally have good accuracy when they are properly calibrated (+/- a fraction of a degree they tend to drift out of adjustment over time. In contrast, even the best humidity sensors are instrinsically no precise (+/- 5% RH is typically the best accuracy that can be achieved at reasonable cost). Humidity sensors out of calibration. To ensure good cooling system performance, all temperature and humidity sensors used by to control system should be treated as maintenance items and calibrated at least once a year. Twice a year is be begin with. After a regular calibration program has been in effect for a while, you can gauge how rapidly your so drift and how frequent the calibrations should be. Calibrations can be performed in-house with the proper equip by a third-party service.						nsically not very sensors also drift used by the year is better to dly your sensors			
EC.A.6	Network the CRAC/CRAH controls	CRAC/CRAH units are ty humidity sensors. The s data center with many dehumidifying. There ma energy. Controlling all ti	ensors may not be (CRACs/CRAHs it is n ay also be significan	calibrated to begin w ot unusual to find so t differences in supp	vith, or they may dri ome units humidifyin oly air temperatures.	ft out of adjustmer g while others are :	nt over time. In a simultaneously			
EC.A.8	Consider disabling or eliminating humidification controls or reducing the humidification setpoint	Tightly controlled humic wider humidity range all economizers. In addition	ows significanť utiliz	ation of free cooling	ı in most climate zor					
EC.A.9	Consider disabling or eliminating dehumidification controls or increasing the dehumidification setpoint	Most modern IT equipment is designed to operate reliably when the intake air humidity is between 20% and 80% RH However, 55% RH is a typical upper humidity level in many existing data centers. Maintaining this relatively low upper limit comes at an energy cost. Raising the limit can save energy, particularly if the cooling system has an airside								
EC.A.10	Change the type of humidifier	Most humidifiers are hea common fuel sources. T uses much less energy. set up properly the drop benefit, as the droplets	he heat of the stea Instead of boiling w plets quickly evapora	m becomes an adde rater, it introduces a ate, leaving no moist	d load on the cooling a very fine mist of w ture on nearby surfa	g system. An evápi ater droplets to thi	orative humidifier e air stream. When			